

TESIS DOCTORAL



UCAM

UNIVERSIDAD CATÓLICA
DE MURCIA

ESCUELA INTERNACIONAL DE DOCTORADO

Programa de Doctorado en Ciencias del Deporte

Optimización de la maquinaria biosaludable: análisis
ergonómico y biomecánico de su eficacia y seguridad

Autor:

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Dr. D. Francisco Esparza Ros

Murcia, octubre de 2025

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RESUMEN

El envejecimiento es un proceso biológico por el cual el organismo se degenera. La acumulación de daño celular y la reducción de la capacidad de regeneración de dichas células producen un deterioro en los diferentes tejidos corporales con el paso del tiempo el cual da lugar al deterioro funcional progresivo y a diferentes tipos de patologías asociadas a la edad. Además, la situación de confinamiento sufrida por las personas mayores durante la pandemia pudo acelerar estos procesos a causa de las restricciones de movilidad, el aislamiento social y el aumento de los comportamientos sedentarios. Por este motivo, en los últimos años ha aumentado el número de investigaciones cuyo objetivo es prolongar la autonomía y la calidad de vida de las personas mayores mediante la promoción de la actividad física en general, y del entrenamiento de fuerza en particular.

En los últimos años, las entidades públicas han optado por diferentes propuestas para mejorar la salud de la población mayor mediante la promoción del entrenamiento de fuerza. Entre las opciones disponibles para cubrir este objetivo se encuentran los parques biosaludables, conocidos popularmente por ser instalaciones deportivas al aire libre que guardan cierta similitud con la maquinaria fitness tradicional, y la cual funciona comúnmente con el propio peso corporal del usuario. A pesar de la gran inversión realizada en estas instalaciones, su validez y seguridad es cuestionada a causa de su escaso respaldo científico. Por este motivo, los objetivos de la presente tesis doctoral fueron: 1) Analizar los efectos del confinamiento sobre parámetros de salud y niveles de fuerza de la población adulta y mayor; 2) Evaluar la disposición sagital del raquis y la inclinación pélvica durante el uso de la maquinaria biosaludable tradicional; 3) Comprobar el efecto de un programa de entrenamiento de fuerza mediante maquinaria biosaludable tradicional sobre la disposición sagital del raquis y la inclinación pélvica en adultos y adultos mayores; 4) Analizar y comparar la actividad electromiográfica registrada durante el uso de maquinaria fitness tradicional indoor, la maquinaria biosaludable tradicional, y los nuevos modelos de maquinaria biosaludable con selector de carga a diferentes intensidades.

El primer objetivo buscó indicar el estado de la población adulta y mayor en la actualidad. Para ello, se presenta un artículo con un diseño observacional longitudinal donde se analizó la evolución durante el confinamiento de diferentes variables relacionadas con la salud como la adherencia a la dieta mediterránea, el nivel de actividad física, variables antropométricas, parámetros sanguíneos, densitometría y la fuerza en una muestra de mujeres mayores.

Ante el segundo objetivo se presenta un segundo artículo de diseño transversal el cual investiga la ergonomía de la maquinaria biosaludable mediante el análisis de la disposición sagital del raquis y la inclinación pélvica durante el uso de maquinaria biosaludable tradicional, para comparar los valores con la posición de bipedestación en adultos y mayores. Además, analiza si ante la imposibilidad de regular de forma individualizada esta maquinaria biosaludable tradicional en función de las características del sujeto, la disposición sagital del raquis y la inclinación pélvica durante la utilización podrían verse afectada por las longitudes, diámetros o las variables de proporcionalidad ósea en adultos y mayores.

Para el cumplimiento del tercer objetivo se presenta el tercer artículo. Se trata de un ensayo aleatorizado controlado donde el grupo experimental realizó un programa de dos sesiones semanales durante ocho semanas de entrenamiento de fuerza en circuito mediante maquinaria biosaludable tradicional. La disposición sagital del raquis e inclinación pélvica fue analizada de forma previa y posterior a la intervención en las posiciones de bipedestación y sedestación, en el grupo de entrenamiento y en el grupo control y de este modo comprobar los posibles efectos del entrenamiento en maquinaria biosaludable tradicional sobre las variables analizadas.

Por último, en respuesta al cuarto objetivo se presentan el cuarto y quinto artículo. El cuarto artículo realiza un estudio sobre la activación electromiográfica de los miembros superiores durante el uso de una máquina fitness tradicional de press de pecho, una máquina biosaludable tradicional semejante, y un nuevo diseño de maquinaria biosaludable con selector de carga, realizando posteriormente una comparación entre la activación muscular de los haces clavicular y esternal del pectoral, la cabeza lateral y larga del tríceps braquial y del deltoides anterior durante el uso de dichas máquinas a diferentes intensidades. En el quinto artículo el protocolo fue similar, a diferencia de que la musculatura analizada fue el recto femoral, el vasto lateral del cuádriceps, el tibial anterior, el bíceps femoral y el

gastrocnemio durante el uso de una máquina fitness tradicional de prensa de piernas, una máquina biosaludables tradicionales de presa de piernas, y el nuevo diseño presentado destinado al entrenamiento de la parte inferior del cuerpo.

El primer estudio mostró como el confinamiento tuvo un impacto negativo mostrando peores resultados tras el confinamiento en el descenso significativo del colesterol HDL (-7.01 ± 1.78 ; $p = .001$), el aumento del LDL (10.30 ± 3.19 ; $p = .003$), del No-HDL (8.73 ± 3.02 ; $p = .007$), y del colesterol/lípidos HDL (0.42 ± 0.08 ; $p < .001$). Respecto a la densitometría, mostró una reducción de la densidad mineral ósea del cuello del fémur (-0.02 ± 0.01 ; $p = .017$), y el aumento en la masa grasa total (0.81 ± 0.24 ; $p = .002$), la masa grasa total del tronco (0.53 ± 0.20 ; $p = .013$) el porcentaje de masa grasa corporal total (0.67 ± 0.21 ; $p = .003$), el porcentaje de masa grasa del tronco (1.06 ± 0.33 ; $p = .003$), y el porcentaje de masa grasa/talla (0.37 ± 0.10 ; $p = .002$). Por último, se mostró la reducción de los niveles de fuerza en pruebas de prensión manual isométrica (-0.87 ± 0.36 ; $p = .023$), y de extensión de rodilla isométrica (-302.80 ± 24.14 ; $p < .001$).

Respecto al segundo estudio, se comprobó como los adultos de mediana y avanzada edad presentaban desalineaciones en el raquis durante el uso de la maquinaria biosaludable con respecto a la posición de bipedestación. Se encontró una disminución significativa de la cifosis torácica en la posición inicial en las máquinas jinete ($p = .006$) y remo ($p = .046$), y un aumento significativo en la posición final en las máquinas remo ($p = .011$), surf ($p < .001$) y paseo ($p = .027$). En relación con la curvatura lumbar y la inclinación pélvica, se observó una disminución significativa de la lordosis lumbar y una disminución de la anteversión pélvica en la posición inicial y final en jinete y remo; y en la máquina ciclostatic ($p < .001$). En la máquina de surf, se observó una disminución significativa de la lordosis lumbar ($p = .002$), sin cambios en la inclinación pélvica. Por otro lado, la talla y el índice córmico fueron las variables que pudieron influir en dichos cambios como covariables.

En el tercer estudio presentado se encontraron mejoras en la disposición sagital del raquis, presentando las máquinas biosaludables tradicionales como unas herramientas útiles para mejorar la salud del raquis de las personas adultas y mayores. En la posición de bipedestación se produjo una reducción significativa de la cifosis torácica en el grupo de entrenamiento tras la intervención ($p < .001$). Por el contrario, el grupo control no mostró diferencias ni en la cifosis torácica ni en la

lordosis lumbar ($p = .863$; $p = .053$), pero sí se produjo una reducción significativa de la inclinación pélvica ($p = .005$). No se observaron cambios en ninguno de los dos grupos en la posición de sedestación excepto una reducción en la lordosis lumbar en el grupo de entrenamiento ($p < .001$).

En el cuarto artículo, se observó que la actividad electromiográfica presentada por el nuevo diseño de maquinaria biosaludable, era significativamente menor que el mostrado en la máquina de fitness tradicional indoor en la musculatura pectoral esternal ($p < .001$), pero mayor en la cabeza lateral del tríceps braquial ($p < .01$; $p < .001$) y el deltoides anterior ($p < .05$; $p < .01$) ante las dos cargas utilizadas (60 y 75% del 1RM). Por el contrario, la maquinaria biosaludable tradicional presentó activaciones significativamente inferiores con respecto a las máquinas con selector de carga en todos los grupos musculares ($p < .001$).

Los resultados del quinto artículo indican que la maquinaria biosaludable tradicional de pres de piernas mostró activaciones significativamente inferiores con respecto a las máquinas con selector de carga en todos los grupos musculares ($p < .001$). Por el contrario, la nueva máquina biosaludable con carga externa sí que consiguió señales electromiográficas similares a la máquina fitness tradicional indoor.

En base a los resultados obtenidos en estos estudios, se han alcanzado las siguientes conclusiones: 1) las personas mayores presentan un empeoramiento de diferentes parámetros sanguíneos, la composición corporal, la densidad mineral ósea, y los niveles de fuerza pudiendo estos aspectos haber sido agravados a causa del confinamiento; 2) la maquinaria biosaludable tradicional aun sin presentar estructuras correctamente diseñadas desde el punto de vista ergonómico para las personas mayores en cuanto a la proporcionalidad y la disposición vertebral en el plano sagital, pueden aportar grandes beneficios sobre la mejora de la disposición sagital del raquis; 3) el entrenamiento de fuerza con maquinaria biosaludable tradicional pueden aportar beneficios sobre la disposición sagital del raquis; 4) una nueva línea de maquinaria biosaludable con selector de carga ha demostrado que puede proporcionar un estímulo similar a nivel de activación eléctrica muscular al encontrado durante el uso de máquinas fitness tradicional indoor, siendo en ambos casos superior a las de la maquinaria biosaludable actual.

PALABRAS CLAVE

Actividad física; Disposición sagital del raquis; Ejercicio; Electromiografía de superficie; Entrenamiento de fuerza; Envejecimiento; Equipamiento fitness al aire libre; Ergonomía; Gimnasio al aire libre; Hipercifosis; Instalación deportiva al aire libre; Máquina guiada; Personas mayores; Postura.

ABSTRACT

Ageing is a biological process through which the organism progressively degenerates. The accumulation of cellular damage and the decline in the regenerative capacity of these cells produce a deterioration in the different body tissues over time, leading to progressive functional decline and different types of age-related pathologies. Moreover, the situation of confinement suffered by the elderly during the pandemic may have accelerated these processes due to mobility restrictions, social isolation and increased sedentary behaviour. For this reason, in recent years there has been an increase in the number of research studies aimed at prolonging autonomy and quality of life through the effects of strength training in the older people.

In recent years, public entities have opted for different proposals to improve the health of the elderly population by promoting strength training. Among these initiatives is the installation of outdoor fitness equipment, commonly referred to as outdoor gyms, which resemble traditional fitness equipment but are installed in open-air environments and typically operate using the user's own body weight. Despite the significant investment in these facilities, their validity and safety have been questioned due to the lack of robust scientific evidence. Therefore, the objectives of this doctoral thesis were: 1) To analyse the effects of confinement on health parameters and strength levels in the adult and older population; 2) To evaluate the sagittal spine disposition and pelvic tilt during the use of traditional outdoor fitness equipment; 3) To test the effect of a strength training programme using outdoor fitness equipment on the sagittal spine disposition and pelvic tilt in adults and older adults; 4) To analyse and compare the electromyographic activity recorded during the use of traditional fitness equipment, traditional outdoor fitness equipment, and new models of outdoor fitness equipment with load selector at different intensities.

The first objective sought to indicate the current state of the adult and elderly population. To this end, an article is presented with a longitudinal observational design in which the evolution during confinement of different health-related variables such as adherence to the Mediterranean diet, the level of physical activity, anthropometric variables, blood parameters, densitometry and strength in older women is analysed.

In response to the second objective, a second article of cross-sectional design is presented which investigates the ergonomics of the outdoor fitness equipment by analysing the sagittal spine disposition, pelvic tilt, and anthropometric proportionality of adults and older adults during the use of traditional outdoor fitness equipment to compare the values with the standing position, in adults and the older people. It also analyses whether, given the impossibility of individually adjusting this traditional outdoor fitness equipment according to the characteristics of the subject, the sagittal arrangement of the spine and pelvic tilt during use could be affected by the lengths, diameters or bone proportionality variables in adults and older people.

To fulfil the third objective, the third article presents. This is a randomised controlled trial in which the experimental group carried out a programme of two sessions per week over eight weeks of circuit strength training using traditional outdoor fitness equipment. The sagittal spine disposition and pelvic tilt was analysed before and after the intervention in the standing and seated positions, in the training group and in the control group, in order to test the possible effects of training on outdoor fitness equipment on the variables analysed.

Finally, in response to the fourth objective, the fourth and fifth articles are presented. The fourth article studies the electromyographic activation of the upper limbs during the use of a traditional chest press fitness machine, a similar traditional outdoor fitness equipment, and a new design of outdoor fitness equipment with a load selector, subsequently making a comparison between the muscular activation of the clavicular and sternal beams of the pectoralis, the lateral and long head of the triceps and the anterior deltoid during the use of these machines at different intensities. In the fifth article the protocol was similar, except that the musculature analysed was the rectus femoris, vastus lateralis of the quadriceps, tibialis anterior, biceps femoris and gastrocnemius during the use of a traditional leg press fitness machine, a traditional outdoor fitness equipment leg press machine, and the new design presented for lower body training.

The first study showed how confinement had a negative impact and showed worse results after this time period in significantly decreased HDL cholesterol (-7.01 ± 1.78 ; $p = .001$), increased LDL (10.30 ± 3.19 ; $p = .003$), Non-HDL (8.73 ± 3.02 ; $p = .007$), and HDL cholesterol/lipids (0.42 ± 0.08 ; $p < .001$). Regarding densitometry, it showed a reduction in femoral neck bone mineral density (-0.02 ± 0.01 ; $p = .017$),

and increase in total fat mass (0.81 ± 0.24 ; $p = .002$), total trunk fat mass (0.53 ± 0.20 ; $p = .013$), total body fat mass percentage (0.67 ± 0.21 ; $p = .003$), trunk fat mass percentage (1.06 ± 0.33 ; $p = .003$), and fat mass/height percentage (0.37 ± 0.10 ; $p = .002$). Finally, reduced strength levels were shown in isometric hand grip (-0.87 ± 0.36 ; $p = .023$), and isometric knee extension (-302.80 ± 24.14 ; $p < .001$) tests.

Regarding the second study, it was found that middle-aged and older adults presented misalignments in the spine during the use of the outdoor fitness equipment with respect to the standing position. A significant decrease in thoracic kyphosis was found in the initial position on the SBR ($p = .006$) and rowing ($p = .046$) machines, and a significant increase in the final position on the rowing ($p = .011$), surfboard ($p < .001$) and air walker ($p = .027$) machines. In relation to lumbar curvature and pelvic tilt, a significant decrease in lumbar lordosis and a decrease in pelvic anteversion was observed in the initial and final position in SBR and rowing; and in the bike machine ($p < .001$). On the surfboard machine, a significant decrease in lumbar lordosis was observed ($p = .002$), with no change in pelvic tilt. On the other hand, height and formic index were the variables that could influence these changes as covariates.

In the third study presented, improvements were found in the sagittal spine disposition, presenting traditional outdoor fitness equipment as useful tools to improve the health of the spine in adults and older people. In the standing position, there was a significant reduction in thoracic kyphosis in the training group after the intervention ($p < .001$). In contrast, the control group showed no difference in either thoracic kyphosis or lumbar lordosis ($p = .863$; $p = .053$), but there was a significant reduction in pelvic tilt ($p = .005$). No changes were observed in either group in the sedentary position except for a reduction in lumbar lordosis in the lumbar training group ($p < .001$).

In the fourth article, it was observed that the electromyographic activity presented by the new design of outdoor fitness equipment was significantly lower than that shown in the traditional indoor fitness machine in the sternal pectoralis muscles ($p < .001$), but higher in the lateral head of the triceps brachii ($p < .01$; $p < .001$) and the anterior deltoid ($p < .05$; $p < .01$) at the two loads used (60 and 75% of 1RM). In contrast, the traditional outdoor fitness equipment presented significantly lower activations with respect to the machines with load selector in all muscle groups ($p < .001$).

The results of the fifth article indicate that the traditional outdoor fitness equipment leg press machine showed significantly lower activations than the load selector machines in all muscle groups ($p < .001$). In contrast, the new outdoor fitness equipment with external load did achieve similar electromyographic signals to the traditional indoor fitness machine.

Based on the results obtained in these studies, the following conclusions have been reached: 1) older people present a worsening of different blood parameters, body composition, bone mineral density, and strength levels and these aspects may have been aggravated by confinement; 2) traditional outdoor fitness equipment, even without presenting structures correctly designed from an ergonomic point of view for older people in terms of proportionality and spine disposition in the sagittal plane, can bring great benefits in terms of improving the sagittal disposition of the spine; 3) strength training with traditional outdoor fitness equipment can bring benefits in terms of improving the sagittal disposition of the spine; 3) strength training with traditional outdoor fitness equipment can provide benefits on sagittal spine disposition; 4) a new line of outdoor fitness equipment with load selector has shown that it can provide a similar stimulus at the level of electrical muscle activation to that found during the use of traditional indoor fitness equipment, being in both cases superior to that of current outdoor fitness equipment.

KEYWORDS

Physical activity; Sagittal spine disposition; Exercise; Surface electromyography; Strength training; Aging; Outdoor fitness equipment; Ergonomics; Outdoor gym; Hyperkyphosis; Outdoor sports facility; Guided machine; Older people; Posture.

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SIGLAS Y ABREVIATURAS

1RM, One-Repetition Maximum
AD, Anterior Deltoid
BIOFIT-LP, BIOFIT Leg Press
BIOFIT-SCP, BIOFIT Seated Chest Press
BMC, Bone Mineral Content
BMD, Bone Mineral Density
BMI, Body Mass Index
BP, Blood Pressure
CG, Control Group
Chol, Total cholesterol
CONSORT, Consolidated Standards of Reporting Trials
COVID-19, Coronavirus disease
CP, Clavicular Heads of the Pectoralis Major
Curv, Curvature
DBP, Diastolic Blood Pressure
DXA, Dual energy X-ray Absorptiometry
EMG, Electromyographic
Exe, Exercise
FM, Fat Mass
FP, Final Position
GPAQ, Global Physical Activity Questionnaire
HDL, High-Density Lipoprotein cholesterol
HL, Healthy Lifestyle
HG, Handgrip Strength
IKE, Maximal Isometric Knee Extension Strength

IP, Initial Position

IPAQ, International Physical Activity Questionnaire

ISAK, International Society for the Advancement on Kinanthropometry

LDL, Low-Density Lipoprotein cholesterol

LHTB, Lateral Heads of the Triceps Brachii

LongHTB, Long Heads of the Triceps Brachii

MDA, Mediterranean Diet Adherence

MIS, maximal Isometric Strength

MVPA, Moderate to Vigorous Physical Activity

OFE, Outdoor Fitness Equipment

OFE-SCP, Classic Outdoor Fitness Equipment Seated Chest Press

OFE-SLP, Classic Outdoor Fitness Equipment Seated Leg Press

PR, Pulse rate

PREDIMED, Prevention with Mediterranean Diet

Reps, Repetitions

RMS, Root Mean Square

SBP, Systolic Blood Pressure

SBR, Single Bonny Rider

SCP, Traditional Seated Chest Press

sEMG, Surface Electromyographic Analysis

SENIAM, Surface Electromyography for the Non-invasive Assessment of Muscles

SLP, Seated Leg Press

SP, Sternal Heads of the Pectoralis Major

T, Time

TG, Training Group

TIDieR, Template for Intervention Description and Replication

Trig, Triglycerides

UL, Unhealthy Lifestyle

WHO, World Health Organization

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I – INTRODUCCIÓN

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La población a nivel mundial está sufriendo un proceso de envejecimiento generalizado. Esto es debido a múltiples causas como el descenso de la natalidad y el aumento de la esperanza de vida como consecuencia, principalmente, del avance sanitario (Gianfredi et al., 2025). Como consecuencia de lo anterior, la esperanza de vida es superior a los 60 años en la mayor parte de la población mundial, pudiendo las personas mayores de 60 años llegar a suponer el 22% del total de la población mundial en la próxima década (OMS, 2018). Además, en el caso de España, se espera que la esperanza de vida supere los 82 años en el 2031, llegando a los 87.28 en el caso de las mujeres, y suponiendo la población mayor de 65 años un 20.8% de la población del país en el 2030 (Instituto Nacional de Estadística, 2022). Sin embargo, el descenso de la actividad física, el aumento del consumo de alimentos procesados, factores socioeconómicos y la proliferación de enfermedades asociadas al envejecimiento han traído como consecuencia que este aumento de la longevidad no esté asociado a una buena calidad de vida en esta última etapa (Esposito et al., 2024; Hu et al., 2024; Starowicz & Filip, 2022; Wei et al., 2022). Entre el 15 y el 25% de la población mayor de 65 años muestra dependencia para las actividades básicas de la vida diaria, elevándose esta cifra al 25-35% para las personas mayores de 75 años, y al 22.5% en hombres y al 30.7% en las mujeres mayores de 85 años (Ministerio de Sanidad, 2014). Por este motivo, se espera que la tasa de dependencia de las personas mayores de 65 años en España ascienda al 36.4% en el 2031 (Instituto Nacional de Estadística, 2022). Es por ello que algunos autores abogan por primar en la investigación como forma de reducir el deterioro a causa del envejecimiento y la morbilidad relacionada con él, y no únicamente el aumento de la esperanza de vida (Brown, 2015).

El envejecimiento es un proceso biológico y multifactorial, el cual consiste en el deterioro funcional progresivo a causa del aumento del daño celular y la reducción de su capacidad de regeneración, lo que implica un deterioro progresivo de la función física a causa del deterioro en los diferentes sistemas y estructuras corporales (Da Silva & Schumacher, 2021; Maldonado et al., 2023). Este proceso degenerativo es el principal factor de riesgo para la aparición de enfermedades

crónicas relacionadas con la edad, como las enfermedades neurodegenerativas, la osteoporosis, la enfermedad pulmonar obstructiva crónica, y el cáncer; y los síndromes geriátricos tales como la fragilidad, la sarcopenia o la dinapenia, entre otras (Franceschi et al., 2018), reduciendo así la calidad de vida, la independencia y la vitalidad de las personas (Noto, 2023).

Recientemente, este proceso de envejecimiento se ha podido ver agravado en la población mayor a causa del confinamiento sufrido durante la pandemia el pasado 2020 (Jahn et al., 2025). El envejecimiento biológico, la reducción de la fuerza, el empeoramiento de la composición corporal y el declive cognitivo son algunos de los aspectos afectados por el paso del tiempo en las personas los cuales sufrieron un aumento durante el periodo de tiempo en el cual las personas mayores sufrieron restricciones de movilidad y aislamiento social (Jahn et al., 2025; Kirwan et al., 2020; Oliveira et al., 2022; Ribeiro de Lima et al., 2021; Visser et al., 2020).

Por otro lado, diferentes factores como la nutrición, la actividad mental y la actividad física pueden cumplir un papel preventivo ante las principales enfermedades relacionadas con la edad (Alcaraz et al., 2024; Izquierdo et al., 2021). Por este motivo, un gran número de entidades públicas han optado por diferentes estrategias de intervención no farmacológicas mediante las cuales ayudar a mejorar la salud de las personas mayores. Se pone así a disposición de los interesados programas de entrenamientos grupales, los cuales han demostrado tener una gran adherencia en personas mayores de 65 años, o mediante la construcción e instalación de algunos elementos específicos en ciertos entornos públicos que favorezcan la práctica de actividad física por parte de este grupo poblacional (Farrance et al., 2016; Komatsu et al., 2020; Manzi et al., 2020). De este modo surgieron los parques biosaludables que se encuentran disponibles en parques, jardines y espacios al aire libre en todas las ciudades.

Las máquinas biosaludables, también conocidas como equipos de fitness al aire libre (OFE), son definidas como aquellas estructuras similares a las máquinas tradicionales que se pueden encontrar en los gimnasios y las salas fitness (Abelleira-Lamela et al., 2024). Este tipo de maquinaria ha sido diseñada con el objetivo de ser segura para los usuarios, además de presentar una alta durabilidad ante las inclemencias meteorológicas o el vandalismo. Este tipo de estructuras son comúnmente localizables en espacios públicos como parques y zonas verdes, permitiendo a los usuarios realizar diferentes tipos de ejercicios al aire libre

mediante los cuales poder mejorar capacidades como la fuerza, la resistencia o la flexibilidad (Bertiato, 2025; Jansson et al., 2019; Marcos-Pardo et al., 2024). La popularidad de este tipo de máquinas se encuentra en auge. Esto se puede deber a dos aspectos clave como su acceso gratuito, o su uso sencillo por parte de los usuarios independientemente de la experiencia previa de estos (Bertiato, 2025; Chow et al., 2017).

Además, en los últimos años, el estudio acerca del uso y funcionamiento de las OFE ha despertado el interés científico a nivel internacional (Chow & Ho, 2018; Chow & Wu, 2019; Fernández-Rodríguez et al., 2020; Hofstetter et al., 2012; Jansson et al., 2019; Marcos-Pardo, Espeso-García, Abelleira-Lamela, et al., 2023; Marcos-Pardo et al., 2024). En esta línea, se han publicado numerosos estudios sobre las OFE que analizando su frecuencia y tipo de uso que comúnmente ha realizado la población con ellas, así como los múltiples beneficios que pueden aportar como el aumento de la fuerza, y la mejora de la función física y la composición corporal (Chow et al., 2017; Chow & Ho, 2018; Chow & Wu, 2019; Jansson et al., 2019; Kim et al., 2018; Marcos-Pardo et al., 2024). Por el contrario, hasta el momento, ninguno de estos estudios ha analizado los efectos de las OFE sobre el propio usuario desde un punto de vista ergonómico, ni han comprobado la activación eléctrica que el entrenamiento con OFE podrían tener sobre la musculatura implicada durante su uso.

Por ello, el presente trabajo se centra en el estudio de los efectos de las OFE sobre la disposición sagital del raquis, así como el análisis la actividad eléctrica muscular durante el uso de las OFE tradicionales, las cuales serán comparadas con maquinaria tradicional fitness semejante, y con sus homólogas procedentes del Proyecto BIO-FitPark, como futura alternativa a las OFE tradicionales.

II – JUSTIFICACIÓN

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La comprensión de los procesos de envejecimiento es esencial. El conocimiento acerca de los diferentes sucesos que se producen en el organismo a causa del deterioro biológico es una herramienta que permite reducir el avance, detener o incluso revertir algunos de esos procesos.

2.1. EL ENVEJECIMIENTO BIOLÓGICO

El envejecimiento biológico es un proceso multifactorial debido principalmente al acortamiento de los telómeros, la acumulación de daño celular, y otras alteraciones, todas ellas interrelacionadas (Rezuş et al., 2020). Los telómeros son estructuras protectoras que se encuentran en los extremos de los cromosomas, cuya función consiste en la protección del material genético durante la división celular, mantener la estabilidad del genoma y evitar la fusión de cromosomas (Blackburn, 1991; McEachern et al., 2000; Zakian, 1995). Su longitud es indicativa de salud y envejecimiento celular (Fasching, 2018; Rezuş et al., 2020; Sánchez-González et al., 2025). Esta es acortada con el paso del tiempo con cada proceso de división celular hasta agotarse, donde entra en un estado de senescencia en el cual no es capaz de seguir replicándose, pero mantiene su función (Pizzul et al., 2023).

A medida que aumenta la edad biológica, otras células también sufren procesos similares. Con el paso del tiempo aumenta la disfunción mitocondrial, las células madre reducen su capacidad regenerativa, y se acumulan proteínas mal plegadas interfiriendo así en la función celular (Morganti & Ito, 2021; Rezuş et al., 2020; Wan & Finkel, 2020). La acumulación de daño celular y diferentes tipos de mutaciones son factores contribuyentes al envejecimiento, afectando a la función celular y tisular, y dando lugar a la pérdida de funciones corporales (Pizzul et al., 2023).

El cúmulo de lesiones a nivel celular puede tener diferentes tipos de repercusiones sobre la funcionalidad de las personas mayores. Su localización dará lugar a diferentes tipos de afecciones causadas por el envejecimiento. Respecto al sistema óseo, es comúnmente cuantificado en el ámbito de la salud mediante una

variable como es la densidad mineral ósea (Bristow et al., 2019; Griffith et al., 2010). Esta variable es indicativa de la concentración de minerales en el hueso, siendo uno de los principales factores que condiciona la resistencia ósea junto a la arquitectura ósea, la capacidad regenerativa, la mineralización y la celularidad (Griffith et al., 2010; Moghadasi & Siavashpour, 2013). El hueso es un tejido vivo y dinámico, el cual sufre un remodelado continuo dependiente de los osteoblastos, células encargadas de sintetizar la matriz orgánica y que permite la mineralización, formando así tejido óseo, y los osteoclastos, células encargadas de la resorción ósea, proceso de descomposición del tejido óseo para la liberación de minerales al sistema sanguíneo (Raggatt & Partridge, 2010; Teitelbaum, 2000). A medida que las personas envejecen aumenta la actividad osteoclástica y disminuye tanto el número como la actividad de los osteoblastos produciéndose una resorción ósea superior a la creación y creando así un balance negativo de tejido óseo (Thapa et al., 2022). Esto es especialmente relevante en las mujeres, donde este proceso se ve agravado a causa de la disminución de estrógenos que se produce durante la menopausia (Thapa et al., 2022). De este modo, se reduce la densidad mineral ósea, haciendo del hueso una estructura frágil y por ende aumentando la probabilidad de fracturas comúnmente asociadas a las personas mayores con especial incidencia en vertebras, muñecas y el cuello del fémur (Thapa et al., 2022).

Respecto a la masa muscular sucede algo similar. Asociada al envejecimiento se encuentra la sarcopenia, patología la cual consiste en la pérdida progresiva y generalizada de la masa musculoesquelética (Chen et al., 2022; Clark & Manini, 2008; Wang et al., 2017; Wilkinson et al., 2018). Este es un proceso multifactorial y progresivo. Con el paso del tiempo la síntesis proteica se ve reducida a causa del aumento de presencia de citoquinas inflamatorias las cuales inhiben la síntesis proteica y aumentan la degradación muscular, por lo que la masa muscular esquelética se ve reducida (Chen et al., 2022; Wang et al., 2017). El sistema hormonal reduce con el paso del tiempo la producción de diferentes hormonas anabólicas como la testosterona, y la hormona del crecimiento entre otras, limitando así la capacidad regenerativa del tejido y favoreciendo el catabolismo (Wang et al., 2017). Además, se produce una denervación de las motoneuronas que inervan grupos de fibras musculares (Larsson et al., 2019; Wilkinson et al., 2018). Esta pérdida suele ser causa de la acumulación de estrés oxidativo, la disminución de factores neurotróficos, o la acumulación de daño mitocondrial (Xu et al., 2025).

A ello se añade la reducción de la capacidad de regeneración de axones dañados a medida que avanza la edad. Se ha comprobado en estudios recientes que estas fibras pueden llegar a ser inervadas por la motoneurona de fibras cercanas a esta mediante conexiones colaterales axonales. Por el contrario, si esto no sucede pierden completamente su función (Hepple & Rice, 2016; Qi et al., 2022; Xu et al., 2025). Esta pérdida de función de forma aislada pero continua reduce paulatinamente la coordinación intramuscular dando lugar a un menor control de la capacidad de producción de fuerza, un menor control del movimiento, la reducción del equilibrio y de la capacidad de control del movimiento (Hepple & Rice, 2016; Pethick & Piasecki, 2022).

2.2. CONSECUENCIAS DEL ENVEJECIMIENTO

La pérdida de masa muscular comienza aproximadamente a partir de los 30 años de edad. Dicha pérdida es de aproximadamente un 1% anual y al alcanzar aproximadamente los 60 años, la velocidad de pérdida incrementa hasta un 20% por década, pudiendo llegar a haber perdido hasta el 50% de la masa muscular con respecto a la presentada durante la juventud antes de los 80 años (Rezuş et al., 2020; Wilkinson et al., 2018). Como consecuencia de lo anterior, se han encontrado que entre el 27 y el 60% de la población mayor de 75 años sufre sarcopenia (Grgic et al., 2020).

Esta pérdida de masa muscular conlleva diferentes problemas. El principal es la pérdida de fuerza, ya que ésta condiciona la potencia, el equilibrio y la funcionalidad, dando lugar a la posibilidad de caídas, fracturas óseas y sedentarismo (Cruz-Jentoft et al., 2019; Larsson et al., 2019). Además, es importante mencionar la dinapenia, siendo definida como la reducción de la capacidad de producción de fuerza, la cual no es únicamente dependiente de la masa muscular, sino que se ve afectada por la reducción de la inervación celular a causa de la edad, la ralentización de la señal eléctrica excitatoria a dichas células, o la reducción de la capacidad de reclutamiento de las fibras musculares (Clark & Manini, 2008; Hepple & Rice, 2016). Esta pérdida de fuerza como consecuencia del envejecimiento puede ser de 2.5-4% al año a partir de los 75 años (Wilkinson et al., 2018). De este modo se suelen presentar bajos niveles de fuerza, así como movimientos poco precisos o

espásticos, siendo estos sucesos agravados con el paso del tiempo (Clark & Manini, 2008; Hepple & Rice, 2016).

Otro de los perjuicios del descenso de la masa muscular es la disminución del gasto energético basal (Shefflette et al., 2023; Wilson & Morley, 2003). Las personas mayores comúnmente presentan una reducción de su masa corporal a causa de la sarcopenia. Esta pérdida de masa corporal se ha visto asociada a un aumento de la fragilidad, aumento del riesgo de fractura de cadera, una peor calidad de vida e incluso un aumento de la probabilidad de muerte (Clark & Manini, 2008; Wilson & Morley, 2003). Este fenómeno consiste en que, a causa del descenso de la masa muscular, tejido metabólicamente activo, se reduce la tasa metabólica basal en reposo, por lo que la persona presenta un menor gasto energético (Shefflette et al., 2023; Wilson & Morley, 2003). Esto puede repercutir sobre los hábitos alimenticios de la persona, disminuyendo el consumo calórico y favoreciendo en mayor medida la sarcopenia. Como consecuencia de lo anterior, algunos estudios indican que un índice de masa corporal se asocia con la pérdida de masa muscular esquelética y la pérdida de peso involuntaria (Kuzuya, 2021). Pero también puede suceder que a pesar de la disminución del gasto metabólico basal se mantenga el consumo de alimentos, derivando esto en un balance energético positivo que traería como consecuencia el aumento de la masa grasa corporal del adulto-mayor, pudiendo así aumentar la probabilidad de adquirir diferentes tipos de enfermedades metabólicas relacionadas con el sobrepeso en personas mayores como la hipertensión, hipercolesterolemia, o la diabetes tipo 2, entre otras (Kuzuya, 2021; Shefflette et al., 2023; Starr et al., 2021).

La función física es otro de los aspectos que se pueden ver condicionados por los cambios en la masa muscular y los niveles de fuerza. La función física, o capacidad funcional es comprendida como la capacidad física que necesita una persona para realizar las actividades cotidianas (Kekäläinen et al., 2023). Una correcta función física mejora la calidad de vida, favorece la autonomía, reduce el riesgo de caída y se relaciona con una menor mortalidad (Kekäläinen et al., 2023). Esta capacidad consiste en el desempeño de diferentes áreas como la capacidad aeróbica, la coordinación, el equilibrio, la fuerza, la flexibilidad, la composición corporal y la cognición (Forman et al., 2017). Una persona mayor con un bajo nivel de capacidad física presentará diferentes niveles de dependencia funcional, así

como limitaciones en las diferentes actividades de su vida diaria (Kekäläinen et al., 2023; Noto, 2023; Shur et al., 2021).

Por último, las personas mayores comúnmente presentan características estructurales tales como las alteraciones de la disposición sagital del raquis y la inclinación pélvica (Ailon et al., 2015; Ohyama et al., 2019). La evidencia científica ha mostrado como se produce un aumento de la curvatura torácica en bipedestación a medida que las personas envejecen (Ailon et al., 2015; Ohyama et al., 2019; Urrutia et al., 2022). En el caso de la curvatura lumbar se ha encontrado controversia, registrando desde la rectificación, hasta el aumento de dicha curvatura (Arshad et al., 2019; Grabara, 2013; Ostrowska et al., 2003). La presencia de estas anomalías ha aumentado en los últimos años, llegando a estar presente la hipercifosis torácica en el 20-40% de la población mayor (Kado et al., 2004, 2007; Pai et al., 2021), y habiendo habido un auge de la incidencia en cuanto a desalineaciones a nivel lumbar (Khalifé et al., 2024; Pai et al., 2021). Estas modificaciones del raquis y la inclinación pélvica pueden estar causadas por factores posturales y musculares. Respecto a la postura, se ha encontrado como la adopción de ciertas posiciones inadecuadas durante largos periodos de tiempo pueden crear adaptaciones en los tejidos blandos de estas estructuras dando lugar a modificaciones (Abelleira-Lamela et al., 2020). Respecto a los niveles de fuerza, se ha encontrado una relación entre los cambios que se producen en la disposición sagital del raquis y la pérdida de fuerza (Hongo et al., 2012; Imagama et al., 2013; Liang et al., 2016; Mika et al., 2005; Rissanen et al., 1995). Concretamente, se ha comprobado la relación entre bajos niveles de fuerza de los músculos extensores del tronco y el aumento de la hipercifosis torácica y de la hiperlordosis o rectificación de la zona lumbar, así como con una alteración de la dinámica lumbo-pélvica (Ailon et al., 2015; Hongo et al., 2012; Kasukawa et al., 2017; Mika et al., 2005). Estas alteraciones raquídeas se han relacionado con problemas respiratorios, pérdida de la función física, reducción de la movilidad, riesgo de caída, dolor de espalda, así como patologías como la espondilólisis, la espondilolistesis, la degeneración de los discos intervertebrales, e incluso la mortalidad (Ailon et al., 2015; Ames et al., 2016; Arja et al., 2003; Been & Kalichman, 2014; Imagama et al., 2013; Jenkins et al., 2021; Kasukawa et al., 2017; Roghani et al., 2024; Wong et al., 2017).

2.3. BENEFICIOS DE LA ACTIVIDAD FÍSICA EN PERSONAS MAYORES

El beneficio de la actividad física sobre sus practicantes es un hecho aceptado por la población y la comunidad científica (Warburton & Bredin, 2017). Los beneficios que pueden aportar de forma tanto aguda como crónica son innumerables. Comenzando desde los beneficios psicológicos, la actividad física ha demostrado mejorar el estado de ánimo, el bienestar emocional, mejora de la autoestima, la prevención del deterioro cognitivo y la reducción del aislamiento (Chen & Nakagawa, 2023; Dale et al., 2019). La liberación de endorfinas, serotonina y dopamina en el organismo durante el ejercicio produce un efecto excitatorio que ayuda al organismo a enfrentar el estrés percibido por el ejercicio, pero que a su vez aporta una sensación de bienestar y motivación a su practicante (Hossain et al., 2024). Además, también tiene un gran efecto social al crear nuevas redes sociales entre las personas, así como fortalecer las ya existentes, además de reducir estigmas y exclusiones o aislamientos comunes en las personas mayores (Barbosa et al., 2023; Cranney et al., 2016; Pedersen et al., 2022).

En cuanto a los beneficios que el ejercicio puede aportar sobre la salud física de los practicantes, también se encuentran ampliamente respaldados por la comunidad científica. Se ha encontrado relación entre la práctica de actividad física y la longitud de los telómeros, y por lo tanto el envejecimiento saludable (Sánchez-González et al., 2025). El ejercicio cardiorrespiratorio, el entrenamiento interválico y altos niveles de actividad física diaria se han visto relacionados sistemáticamente con una mayor longitud de los telómeros a causa de la mayor actividad de la telomerasa. Del mismo modo el entrenamiento de fuerza mediante maquinaria guiada en circuito no estimuló la telomerasa, pero obtuvo resultados positivos, posiblemente gracias a la reducción del estrés oxidativo y la inflamación (Sánchez-González et al., 2025; Werner et al., 2019).

La actividad física también repercute sobre otros componentes corporales como la masa ósea, la masa grasa o la masa muscular. El correcto estado de la composición corporal es esencial para el mantenimiento de la homeostasis metabólica y un adecuado estado de salud que contribuyan a un envejecimiento saludable (Ponti et al., 2020). Respecto a la masa ósea, existe una relación directa de este componente con la actividad física en los mayores (Moghadasi & Siavashpour, 2013). Se ha comprobado como niveles más altos de actividad física se asocian de

forma positiva con la densidad mineral ósea en brazos, pelvis y piernas en muestras de adultos mayores, e incluso se encontró una correlación negativa entre la densidad mineral ósea de la pelvis y el tiempo sedentario (Buttan et al., 2020). Estos datos indican como una actividad física regular puede mantener la salud ósea de las personas mayores, mejorando la densidad mineral ósea y reduciendo a su vez el riesgo de fractura ante caídas (Cauley & Giangregorio, 2020; O'Bryan et al., 2022). Además, es recomendable la práctica de la actividad física al aire libre para así conseguir una mayor exposición solar mediante la cual se obtiene vitamina D que interviene en la recomposición estructural del hueso, que junto con la carga mecánica producida sobre el hueso que actividades como andar, correr o el trabajo de fuerza aportan sobre él, fortalece su estructura (Yue et al., 2024). A causa de estos beneficios, han sido desarrolladas múltiples intervenciones no farmacológicas de entrenamiento sobre la población mayor con el objetivo de mejorar la densidad mineral ósea, encontrando una dosis efectiva en entrenamientos que combinaban el componente cardiorrespiratorio y de fuerza muscular, o en sesiones de entrenamiento de fuerza, con sesiones de 1 hora y frecuencias de 2-3 sesiones semanales (Pinheiro et al., 2020; Xiaoya et al., 2025).

La masa grasa es otro de los tejidos que se ven afectados por el envejecimiento, y su relación con la hipertensión, diabetes, cáncer, enfermedades cardíacas y la probabilidad de muerte han hecho de su reducción un elemento esencial en la sanidad pública (Bann et al., 2014; Franceschi et al., 2018; Guo et al., 2019). Para ello la actividad física cumple un rol imprescindible viéndose relacionados los niveles de actividad física en el tiempo libre con una menor cantidad de masa grasa (Bann et al., 2014). Investigaciones previas han mostrado como protocolos de entrenamiento y dieta puede obtener resultados significativamente superiores a los obtenidos realizando únicamente dieta en la reducción de la masa grasa en adultos mayores (Beavers et al., 2017). Además, en personas mayores independientes se ha visto como intervenciones mediante entrenamiento de fuerza también pueden obtener reducciones de la cantidad de masa grasa total y porcentual (González-Rocha et al., 2022).

Por último, entre los tres componentes principales de la composición corporal se encuentra la masa muscular. Este tejido es el principal afectado a causa del envejecimiento. A medida que las personas envejecen aumenta la resistencia

anabólica del músculo, por la cual reduce su respuesta ante estímulos que promueven la síntesis proteica muscular como el ejercicio físico (Burd et al., 2013). Además, la actitud sedentaria que presenta un gran porcentaje de la población mayor extiende la debilidad muscular entre la población. Por el contrario, se ha visto como una mayor actividad física diaria se relaciona con una mayor masa magra apendicular (Bann et al., 2014). Además, en la población activa se ha comprobado como 30 minutos diarios de actividad física de intensidad moderada-vigorosa se asocian con la reducción de la posibilidad de padecer sarcopenia severa y obesidad sarcopénica en adultos mayores (Aggio et al., 2016). Esto demuestra como estímulos de un relativo bajo volumen y una intensidad media-alta pueden ser suficientes para ralentizar el efecto del envejecimiento sobre el músculo. Siguiendo este proceso, múltiples investigaciones han analizado el posible efecto de diferentes tipos de intervenciones basadas en el entrenamiento de fuerza en la población mayor con el objetivo de aumentar la masa y la fuerza muscular. Se ha mostrado como entrenamientos de fuerza con duraciones de entre 8 y 12 semanas, con 3 sesiones semanales utilizando intensidades entre el 60 y el 80% del 1RM durante 3-4 series por ejercicio y 8-12 repeticiones por serie, pueden prevenir la pérdida de masa muscular (Borde et al., 2015). A su vez, programas de 10 a 18 semanas de duración con 2-3 sesiones semanales mostraron capacidad de incluso aumentar el tamaño muscular (Grgic et al., 2020). Por ello, será importante controlar el volumen total de entrenamiento junto a la intensidad y el tiempo bajo tensión para obtener hipertrofia en el adulto mayor (Borde et al., 2015).

Este aumento en la masa muscular puede aportar múltiples beneficios a las personas mayores (Pethick & Piasecki, 2022). Entre ellos, el entrenamiento de fuerza destinado a la hipertrofia puede mejorar la sensibilidad a los estímulos anabólicos, paliando parte del efecto de la resistencia anabólica producida por la edad (Burd et al., 2013). Mediante el aumento de la cantidad de masa muscular se podría obtener un aumento de la tasa metabólica basal, así como una regulación de diferentes tipos de procesos metabólicos y hormonales. Se ha encontrado una relación positiva entre la cantidad de masa muscular y los niveles de testosterona en adultos, así como indicando los beneficios que esta tiene a la hora de conservar la masa muscular a lo largo del tiempo (Shigehara et al., 2022). Además, el entrenamiento de fuerza también ha mostrado aumentos de testosterona, estrógenos y hormona del crecimiento en una población femenina tras un periodo

de 12 semanas, obteniendo por ende la estimulación de hormonas colaboradoras en el proceso de formación de hueso (Moghadasi & Siavashpour, 2013).

Este tipo de intervenciones no solo aumenta la cantidad de masa muscular, sino que también puede aumentar la capacidad de producción de fuerza (Borde et al., 2015; Cannataro et al., 2022; Moghadasi & Siavashpour, 2013; O'Bryan et al., 2022). Factores esenciales como la carga externa, el volumen, o el tiempo bajo tensión pueden ser la causa al favorecer el reclutamiento de un mayor número de unidades motoras cuando estos son más elevados (Grgic et al., 2020). Además, se ha visto como ante intensidades más altas, la frecuencia de disparo en las unidades motoras aumenta (Cormie et al., 2011). Estos dos hechos permiten que las personas ejerzan más fuerza y más potencia, de forma más estable y durante más tiempo, aumentando así su funcionalidad y reduciendo el número de problemas asociados a la debilidad y la fragilidad (Cardozo et al., 2019; Cormie et al., 2011; Grgic et al., 2020; Kirk et al., 2024). Estudios previos han comprobado tanto la relevancia de la velocidad de ejecución de fuerza sobre la funcionalidad, como la relevancia ante acciones tan cotidianas como la marcha (Clark et al., 2013; Hester et al., 2021). Por lo que los niveles de fuerza podrán condicionar la funcionalidad de las personas en edades avanzadas.

En este aspecto, la actividad física, también ha mostrado mejoras en la funcionalidad de las personas mayores. Estudios realizados mediante el seguimiento de personas mayores de 75 años durante la práctica de actividades grupales mostraron diferencias significativas del grupo activo con respecto al grupo control en todos los test funcionales, entre lo que se encontraban el 30s Sit-to-stand, el 5 Sit-to-stand repetitions y el Timed Up and Go (Pedersen et al., 2022). En su mayoría las pruebas empleadas, presentaban un componente de fuerza en diferentes expresiones, en su mayoría mediante el uso del peso corporal.

Por último, estos componentes físicos pueden tener repercusiones sobre el raquis. Esta estructura condiciona aspectos tales como el equilibrio y el riesgo de caídas en las personas mayores (Imagama et al., 2013). Por este motivo, y a causa de la dependencia de los niveles de fuerza de la musculatura extensora del tronco (Ailon et al., 2015; Hongo et al., 2012; Kasukawa et al., 2017; Mika et al., 2005), en los últimos años se han buscado diferentes métodos de entrenamiento para mejorar la disposición sagital del raquis (Glassman et al., 2006; González-Gálvez et al., 2019;

Kernc et al., 2018; Ponzano et al., 2021). En su mayoría, las intervenciones son realizadas mediante un diseño multicomponente, en las cuales se combina el entrenamiento de fuerza junto con ejercicios de estiramiento o de higiene postural (González-Gálvez et al., 2019; Jenkins et al., 2021). El seguimiento de forma sistemática durante al menos ocho semanas de este tipo de intervenciones que incluyen ejercicios de fuerza general, fortalecimiento muscular del tronco, ejercicios de movilidad articular y estiramientos dirigidos a la musculatura asociada al tronco han conducido a una reducción de las curvaturas sagitales en bipedestación (González-Gálvez et al., 2019; Jang et al., 2019; Jenkins et al., 2021). A pesar de sus efectos, una reciente revisión sugirió como el entrenamiento multicomponente podría no ser la mejor alternativa para la mejora de la disposición sagital del raquis a causa de la baja-moderada calidad de los estudios analizados (Jenkins et al., 2021). Por otro lado, son escasos los trabajos en los cuales se emplea únicamente entrenamiento de fuerza (Ames et al., 2016; Bergström et al., 2011; Harding et al., 2021; Watson et al., 2019), no permitiendo así analizar su efecto de forma aislada sobre las mejoras en la disposición sagital del raquis, siendo además escasos los estudios realizados en la población mayor (Jang et al., 2019; Jenkins et al., 2021; Katzman et al., 2017; Watson et al., 2019). Estudios realizados en mujeres posmenopáusicas y hombres mayores de 45 años con una densidad mineral ósea baja descubrieron que, tras entrenar utilizando intensidades del 80-85% de una repetición máxima, se observó una disminución significativa de la cifosis torácica tras ocho semanas de entrenamiento (Harding et al., 2021; Watson et al., 2019). Por el contrario, otros estudios no encontraron mejoras significativas, posiblemente debido a la baja intensidad del programa de fuerza realizado mediante bandas elásticas (Bergström et al., 2011). A su vez, trabajos que emplearon maquinaria de entrenamiento de fuerza guiada encontraron una disminución de la cifosis torácica, pero señalaron que aspectos como una mala elección de las máquinas guiadas o seleccionar ejercicios que impliquen tracciones del core o zona lumbar y elevaciones verticales de la carga, o la ejecución isométrica del ejercicio pudieron provocar fracturas vertebrales (Harding et al., 2021). Por estos motivos, una revisión ha indicado como aspectos clave para generar cambios en la disposición sagital del raquis a nivel torácico el volumen de entrenamiento y la correcta selección del equipamiento que pueda proporcionar carga suficiente,

especialmente cuando se trabaje la musculatura del tronco como musculatura sinergista durante otros ejercicios (Katzman et al., 2017).

2.4. MAQUINARIA BIOSALUDABLE

Ante el gran número de beneficios que se pueden obtener mediante la actividad física y sus repercusiones, numerosas entidades gubernamentales de diferentes países han aumentado en los últimos años la inversión en espacios públicos activos tales como senderos, carilles para bicicletas, zonas de juego infantil, o zonas para la práctica deportiva (Burillo et al., 2011; Chow, 2013; Lee & Ho, 2021). Estos espacios han demostrado su potencial a la hora de promover la actividad física en la población (Burillo et al., 2011; Lee & Ho, 2021; Zhang et al., 2022), siendo la instalación de estructuras destinadas para la práctica de ejercicio una de las más prometedoras a la hora de fomentar la práctica de actividad física (Zhang et al., 2022). La promoción de este tipo de estructuras comenzó en el siglo XXI con la instalación de barras para realizar dominadas y ejercicios de autocarga junto a senderos localizados en zonas públicas (Lee & Ho, 2021). Estas instalaciones evolucionaron hasta alcanzar las estructuras destinadas de una forma más específica a las personas mayores, encontrando un primer registro en China en el año 1995 y expandiéndose en las últimas décadas por toda América, Europa y Asia (Jansson et al., 2019; Lee & Ho, 2021).

Estas máquinas son descritas como aparatos fijos, robustos y duraderos que no requieren de electricidad, sino que utilizan el peso corporal del usuario como resistencia, pero presentando un uso sencillo y que además se encuentran instalados en espacios abiertos como parques (Cranney et al., 2016; Jansson et al., 2019). Este tipo de instalaciones está especialmente orientada a las personas mayores al permitir exclusivamente el trabajo con autocarga, los cuales además son sus principales usuarios (Chow et al., 2017; Jansson et al., 2019). Su principal objetivo es la promoción de la actividad física en las personas mayores, junto al fomento de las relaciones interpersonales, así como la prevención de exclusión de las personas mayores en la sociedad (Barbosa et al., 2023; Cranney et al., 2016; Lee & Ho, 2021). Pero, además, los usuarios las utilizan por motivos como el mantenimiento de la salud física y mental, su ubicación en el medio natural, su fácil

acceso, su gratuidad, o la búsqueda de la mejora de la composición corporal (Chow, 2013; Cranney et al., 2016; Jansson et al., 2019; Lee & Ho, 2021).

Estas instalaciones comúnmente se encuentran adaptadas a la población mayor con suelos acolchados y pasamanos, por lo que estas lo perciben como un entorno seguro (Lee & Ho, 2021). Como otra característica y siendo percibido de forma positiva por algunos usuarios, comúnmente consisten en ejercicios de bajo impacto e intensidad ligera (Lee & Ho, 2021). Por el contrario, los usuarios asiduos han llegado a expresar inquietudes acerca del diseño y funcionamiento de los equipos, expresando la necesidad de una mayor variedad de maquinaria para el entrenamiento de la fuerza, así como un mayor nivel de intensidad con el fin de aumentar la motivación para su uso (Paudel et al., 2024). Este aspecto podría ser subsanado mediante máquinas que permitiesen mantener tanto intensidades altas como ligeras mediante la inclusión de un sistema regulable (Chow & Ho, 2018). Aun así, habría que tener en cuenta el diseño y funcionamiento de las OFE, ya que estos condicionan el estímulo de esfuerzo percibido por el practicante (Grigoletto et al., 2021), por lo que cada máquina debe ser examinada de forma concreta para su correcto uso.

Otros de los aspectos negativos percibidos por los usuarios fue el mal estado y la falta de mantenimiento de las máquinas que habitualmente se encuentran en los parques, comúnmente causado por el comportamiento incívico, el vandalismo y el deterioro por el paso del tiempo (Chow, 2013; Chow et al., 2021; Lee & Ho, 2021). Además, se ha comprobado como la calidad de las instalaciones condiciona en mayor medida a la población con respecto a aspectos tales como la proximidad a la hora de practicar actividad física (Jansson et al., 2019). Por último, respecto a su diseño, la ausencia de carga ha provocado que algunos usuarios realizasen movimientos balísticos durante su ejecución, así como la adopción de determinadas posturas en algunas máquinas que suponen un riesgo para su integridad (Chow & Wu, 2019). Por este motivo un panel de expertos indicó que aún bajo un diseño no ideal de la maquinaria, si los usuarios son conscientes de la técnica y la postura durante su uso, estas podrían ser seguras (Chow & Wu, 2019), pero por el contrario no existe evidencia que respalde la capacidad de los usuarios para ello.

Por otro lado, a pesar de su popularidad, la efectividad de la maquinaria biosaludable está en entredicho, ya que las intervenciones realizadas mediante su

uso además de escasas son inciertas en sus resultados. El análisis del consumo energético durante su uso por personas mayores mostró intensidades ligeras y moderadas dependiendo de la máquina seleccionada (Chow & Ho, 2018). Por otro lado, dos estudios de intervención, ambos de 12 semanas de duración encontraron resultados opuestos. Un primer trabajo basado en entrenamiento supervisado que combinaba marcha y entrenamiento en maquinaria mostró mejoras en diferentes tipos de test funcionales (Barbosa et al., 2023). Por el contrario, el mismo trabajo al presentar otro grupo sin supervisar pero que utilizó únicamente maquinaria biosaludable, únicamente encontró mejoras significativas en su estilo de vida (Barbosa et al., 2023). Por otra parte, un estudio el cual basó su intervención en la combinación de trabajo cardiorrespiratorio, de fuerza y flexibilidad mediante maquinaria biosaludable no encontró mejoras significativas, lo que podría haber sido consecuencia de la falta de un componente de resistencia y a causa del diseño de la maquinaria (Liu et al., 2020). Por lo tanto, en general estas instalaciones tienen un potencial beneficio para la salud mediante su uso, pero el número de investigaciones que lo respalde aún es limitado (Jansson et al., 2019; Marcos-Pardo et al., 2024), por lo que se desconoce su implicación sobre el organismo durante su uso y las posibles adaptaciones a obtener.

Además, ninguno de los estudios previos ha analizado si son seguras para la disposición sagital del raquis ni la capacidad que tienen de activar la musculatura supuestamente implicada durante su ejecución. Por estos motivos es esencial aumentar la evidencia científica acerca de la maquinaria biosaludable, al ser una herramienta a disposición de toda la población y disponibles en espacios al aire libre en muchas ciudades y países, pero la cual carece de un respaldo contrastado de su efectividad y seguridad.

III – OBJETIVOS

III - OBJETIVOS

3.1. OBJETIVOS GENERALES

1. Analizar las consecuencias de utilizar maquinaria biosaludable y el efecto de su implementación durante un programa de entrenamiento de fuerza sobre la disposición sagital del raquis e inclinación pélvica.
2. Evaluar la efectividad de los nuevos modelos de maquinaria biosaludable con respecto a la maquinaria biosaludable actual y la maquinaria fitness tradicional.

3.2. OBJETIVOS ESPECÍFICOS

1. Analizar los efectos de 13 semanas de confinamiento por COVID-19, sobre diferentes parámetros de salud: nivel de actividad física, adherencia a la dieta mediterránea, medidas antropométricas, parámetros sanguíneos, parámetros de densitometría y niveles de fuerza muscular de mujeres mayores.
2. Analizar la disposición sagital del raquis y la inclinación pélvica al utilizar maquinaria biosaludable, así como determinar la influencia de las variables antropométricas sobre estos factores en personas adultas y mayores.
3. Analizar el efecto de un programa de entrenamiento de fuerza mediante maquinaria biosaludable sobre la disposición sagital del raquis y la inclinación pélvica de adultos y adultos mayores.
4. Analizar y comparar la señal electromiográfica registrada en los grupos musculares del miembro superior al utilizar una máquina fitness tradicional de pres de pecho, una máquina biosaludable tradicional de pres de pecho y una máquina de empuje perteneciente a una nueva línea de maquinaria biosaludable ante diferentes cargas.
5. Analizar y comparar la señal electromiográfica de los grupos musculares del miembro inferior al utilizar una máquina fitness tradicional de prensa de piernas, una máquina biosaludable tradicional de prensa de piernas, y

una máquina de prensa de piernas perteneciente a una nueva línea de maquinaria biosaludable ante diferentes cargas.

3.3. GENERAL OBJECTIVES

1. To analyse the consequences of the use of outdoor fitness equipment and the effect of its use during strength training on the sagittal disposition of the spine.
2. To evaluate the affectivity of new models of outdoor fitness equipment with respect to current outdoor fitness equipment and traditional fitness equipment.

3.4. SPECIFIC OBJECTIVES

1. To analyse the effects of 13 weeks of confinement by COVID-19 on different health parameters: level of physical activity, adherence to the Mediterranean diet, anthropometric measurements, blood parameters, densitometry parameters and muscle strength levels in older women.
2. To analyse the sagittal disposition of the spine and pelvic tilt during the use of traditional outdoor fitness equipment, as well as to determine the influence of anthropometric variables on these factors in adults and older people.
3. To analyse the effect of a strength training programme using outdoor fitness equipment on the sagittal spine disposition and pelvic tilt in middle-aged and older adults.
4. To analyse and compare the electromyographic signal recorded in the muscle groups of the upper limb during the use of a Seated Chest Press, a traditional outdoor fitness equipment chest press machine and a push machine belonging to a new line of outdoor fitness equipment under different loads.
5. To analyse and compare the electromyographic signal of the muscle groups of the lower limb when performing a Seated Leg Press with traditional fitness equipment, a traditional outdoor fitness equipment leg press machine, and a leg press machine belonging to a new line of outdoor fitness equipment at different loads.

IV - HIPÓTESIS

IV -HIPÓTESIS

4.1. HIPÓTESIS GENERALES

1. La maquinaria biosaludable tradicional conllevará a la adopción de posturas en las cuales se producen desalineaciones de la disposición sagital del raquis. Aun así, el entrenamiento de fuerza mediante estas será efectivo para mejorar la disposición sagital del raquis en posturas relajadas.
2. La maquinaria biosaludable tradicional presentará una menor actividad eléctrica muscular con respecto a los nuevos diseños de máquinas biosaludable. Además, los nuevos modelos de maquinaria biosaludable con carga regulable presentarán señales de actividad electromiográficas similares a la maquinaria fitness tradicional.

4.2. HIPÓTESIS ESPECÍFICAS

1. De acuerdo a estudios previos en los cuales personas mayores estuvieron expuestas a una reducción de su movilidad, se espera que el confinamiento repercuta negativamente sobre las variables de salud y fuerza de las mujeres mayores.
2. Se producirán cambios en la disposición sagital del raquis y la inclinación pélvica al utilizar maquinaria biosaludable y estos cambios dependerán de parámetros antropométricos relacionados con las características óseas estructurales en adultos de mediana y avanzada edad.
3. El entrenamiento de fuerza mediante maquinaria biosaludable mejorará la disposición sagital del raquis y la inclinación pélvica de los adultos y adultos mayores.
4. La señal electromiográfica de la musculatura del miembro superior será similar entre las máquinas que permiten la selección de carga externa (Máquina fitness tradicional de pres de pecho y el nuevo diseño de

maquinaria biosaludable de pres de pecho), y la activación será mayor en las máquinas de fitness tradicional de pres de pecho y el nuevo modelo de maquinaria biosaludable de pres de pecho en comparación con una máquina que sólo permite trabajar con el propio peso corporal (Máquina biosaludable tradicional de pres de pecho). Además, la señal electromiográfica registrada será mayor al 75% de 1RM que al 60% de 1RM en las máquinas de fitness tradicional de pres de pecho y el nuevo modelo de maquinaria biosaludable de pres de pecho.

5. La señal electromiográfica de la musculatura de los miembros inferiores será similar entre las máquinas que permiten la selección de carga externa (Máquina fitness tradicional de pres de piernas y el nuevo diseño de maquinaria biosaludable de pres de piernas), y la activación será mayor en las máquinas máquina fitness tradicional de pres de piernas y el nuevo diseño de maquinaria biosaludable de pres de piernas en comparación con una máquina que sólo permite trabajar con el propio peso corporal (Máquina biosaludable tradicional de pres de piernas). Además, la señal electromiográfica registrada será mayor al 75% de 1RM que al 60% de 1RM en las máquinas máquina fitness tradicional de pres de piernas y el nuevo diseño de maquinaria biosaludable de pres de piernas.

4.3. GENERAL HYPOTHESIS

1. The traditional outdoor fitness equipment will lead to the adoption of postures in which misalignments of the sagittal spine disposition occur. Even so, strength training with these will be effective in improving the sagittal spine disposition in relaxed postures.
2. Traditional outdoor fitness equipment will present less muscular electrical activity with respect to the new model of outdoor fitness equipment. In addition, new model of outdoor fitness equipment will present electromyographic signals similar to traditional fitness equipment.

4.4. SPECIFIC HYPOTHESIS

1. According to previous studies in which older people were exposed to a reduction in their mobility, it is expected that confinement will have a negative impact on health and strength variables in older women.
2. Changes in the sagittal disposition of the spine and pelvic tilt will occur during the use of traditional outdoor fitness equipment and that these changes will depend on anthropometric parameters related to structural bone characteristics in middle-aged and older adults.
3. Strength training using traditional outdoor fitness equipment will improve the sagittal disposition of the spine and pelvic tilt in adults and older adults.
4. The electromyographic signal of the upper limb musculature will be similar between machines that allow external load selection (Traditional seated chest press and Classic outdoor fitness equipment seated chest press), and activation will be greater on Traditional seated chest press and Classic outdoor fitness equipment seated chest press machines compared to a machine that only allows working with one's own body weight (Classic outdoor fitness equipment seated chest press). In addition, the electromyographic signal recorded will be greater at 75% of 1RM than at 60% of 1RM on the Traditional seated chest press and Classic outdoor fitness equipment seated chest press.

5. The electromyographic signal of the lower limb musculature will be similar between machines that allow external load selection (Seated leg press and BIOFIT leg press), and activation will be greater on Seated leg press and BIOFIT leg press machines compared to a machine that only allows working with one's own body weight (Classic outdoor fitness equipment seated leg press). In addition, the electromyographic signal recorded will be higher at 75% of 1RM than at 60% of 1RM on the Seated leg press and BIOFIT leg press machines.

V – MATERIAL, MÉTODO Y RESULTADOS

V - MATERIAL, MÉTODO Y RESULTADOS

El apartado de Material, Método y Resultados de la presente tesis doctoral se compone de los siguientes artículos científicos publicados en revistas indexadas las cuales presentan un proceso de revisión por pares.

Artículo 1.

Marcos-Pardo, P. J., Abelleira-Lamela, T., González-Gálvez, N., Esparza-Ros, F., Espeso-García, A., & Vaquero-Cristóbal, R. (2022). Impact of COVID-19 lockdown on health parameters and muscle strength of older women: A longitudinal study. *Experimental Gerontology*, 164(111814), 111814. <https://doi.org/10.1016/j.exger.2022.111814>

JCR Impact Factor: 3,9; Quartile: Q2; Category: Geriatric & Gerontology (27/54).

Artículo 2.

Abelleira-Lamela, T., Vaquero-Cristóbal, R., González-Gálvez, N., Esparza-Ros, F., Espeso-García, A., & Marcos-Pardo, P. J. (2021). Sagittal spine disposition and pelvic tilt during outdoor fitness equipment use and their associations with kinanthropometry proportions in middle-aged and older adults. *PeerJ*, 9(e12657), e12657. <https://doi.org/10.7717/peerj.12657>

JCR Impact Factor: 3,061; Quartile: Q2; Category: Multidisciplinary Sciences (33/74).

Artículo 3.

Marcos-Pardo, P. J., Abelleira-Lamela, T., Vaquero-Cristóbal, R., Espeso-García, A., Esparza-Ros, F., & González-Gálvez, N. (2025). Improving spinal alignment through innovative resistance training with outdoor fitness equipment in middle-aged and older adults: a randomized controlled trial. *Scientific reports*, 15, 14499. <https://doi.org/10.1038/s41598-025-99061-1>

JCR Impact Factor: 3,8; Quartile: Q1; Category: Multidisciplinary Sciences (25/134).

Artículo 4.

Abelleira-Lamela, T., Marcos-Pardo, P. J., Abraldes, J. A., González-Gálvez, N., Espeso-García, A., Esparza-Ros, F., & Vaquero-Cristóbal, R. (2024). Comparative electromyographic analysis in leg press of traditional fitness equipment, traditional outdoor fitness equipment, and a new model of outdoor fitness equipment in trained young men. *Applied Sciences (Basel, Switzerland)*, 14(16), 7390. <https://doi.org/10.3390/app14167390>

JCR Impact Factor: 2,5; Quartile: Q1; Category: Engineering, Multidisciplinary (44/181).

Artículo 5.

Abelleira-Lamela, T., Marcos-Pardo, P. J., Abraldes, J. A., González-Gálvez, N., Espeso-García, A., Esparza-Ros, F., & Vaquero-Cristóbal, R. (2024). Electromyographic comparison of traditional fitness machines, outdoor fitness equipment without load selectors, and outdoor fitness equipment with load selectors in a seated chest press exercise in trained young men. *Sensors*, 24(23), 7740. <https://doi.org/10.3390/s24237740>

JCR Impact Factor: 3,4; Quartile: Q2; Category: Instruments & Instrumentation (24/76).

**ESTUDIO 1: IMPACT COVID-19
LOCKDOWN ON HEALTH PARAMETERS
AND MUSCLE STRENGTH OF OLDER
WOMEN: A LONGITUDINAL STUDY**

Va - ESTUDIO 1 - Impact of COVID-19 lockdown on health parameters and muscle strength of older women: A longitudinal study

5.1. ABSTRACT

Objetives: The present study aimed to evaluate the effect of a 13-week COVID-19 lockdown on health-related parameters in women aged 60–70 years.

Study design: Thirty women participated in this longitudinal study. All the assessments were performed before and 13 weeks after the initial phase of the COVID-19 pandemic in Spain (March to June 2020).

Main outcome measures: A sociodemographic questionnaire was provided, and tests were performed to assess muscle strength, anthropometric measurements, densitometry, blood pressure, blood parameters, Mediterranean diet adherence, and physical activity levels.

Results: After the lockdown, both healthy and unhealthy lifestyle groups showed a significant worsening of HDL, cholesterol/HDL lipids, and isometric knee extension strength parameters. However, individuals with an unhealthy lifestyle also showed a significant worsening in LDL lipids, Non-HDL lipids, bone mineral density of the femoral neck, fat mass/height (%), truncal fat mass (absolute and percentage), total fat mass (absolute and percentage) and handgrip strength.

Conclusions: The COVID-19 pandemic had a negative impact on the overall health status of Spanish older women, potentially increasing their susceptibility to comorbidities, such as lipid cholesterol, body fat, and decreased muscle strength.

5.2. INTRODUCTION

The Coronavirus disease (COVID-19) has become the world's leading health news headline. Health authorities in most countries have imposed certain restrictions to prevent the spread of the virus. Unfortunately, these restrictions inevitably disrupted the daily activities of tens of millions of people, with lockdown becoming a trigger for the deterioration of physical capacity, specially in older population who may have suffered the most from confinement and post-confinement (Palmer et al., 2020).

COVID-19 lockdown could have affected some health parameters, such as level of physical activity and diet, which are risk factors for several cardiovascular and metabolic diseases, such as hypertension, dyslipidaemia and obesity (Bellettiere et al., 2019; Chen et al., 2020; Colpani et al., 2018). About the reduction of the physical activity, long hours at home may lead to increased sedentary behavior and inactivity, long periods of sitting and lying down; all of which increases the risk of developing or exacerbating chronic diseases (Owen et al., 2010; Pharr et al., 2018). Additionally, this isolation resulted in changes in dietary intake of adults and older people that may have increase body fat, accelerated sarcopenia and led to a decline in muscle mass and strength (Marcos-Pardo et al., 2020).

Most of the longitudinal studies on the effects of lockdown due to COVID-19 have been conducted with young or adult populations, but there are hardly any studies with older people (Ribeiro de Lima et al., 2021). Therefore, the aim of the present study was to analyze the effects of 13-week of lockdown due to COVID-19, on different health parameters: physical activity level, Mediterranean diet adherence, anthropometric measurements, blood parameters, densitometry parameters, and muscle strength levels of older women.

5.3. METHODS

5.3.1. Design

This study is a part of the ongoing project (ClinicalTrials.gov Identifier: NCT04958499). Pre-test measurements were taken to begin the intervention specified in this clinical trial. However, this intervention could not be carried out due to COVID-19 pandemic. Instead, the present research was conducted, for which external funding was obtained, with additional permission provided by the institutional ethics committee for it to be carried out. This longitudinal study design followed the Strobe Statement (von Elm et al., 2008).

5.3.2. Participants

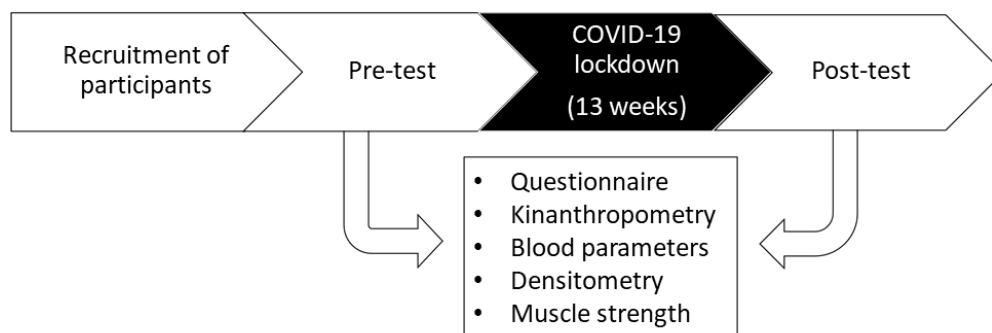
The participants were volunteer woman form the nearby areas of the institution. The sample was collected through announcements in women's centers,

senior centers, social centers and health centers in nearby areas. Thirty Spanish women between 60 and 70 years of age participated in the study. The inclusion criteria were: being between 60 and 70 years of age and being female. Participants with smoking, selfreported alcohol dependence, chronic kidney disease, infectious diseases and/or coronary heart disease were excluded from the study. This research could present response bias. Women who came voluntarily to participate in the research could be the most concerned about their health; leaving out of it those women who have a worse lifestyle.

Before the start of the research protocol, all the participants were informed about the experimental protocol (objectives, methods, benefits and risks). All the women underwent assessments before (pre) and after (post) the 13-week period of COVID-19 pandemic isolation (Fig. 1). The pre-tests were performed in February 2020, and the post-tests were performed in June 2020.

Rstudio 3.15.0 software was used to establish the sample size. The significance level was set at $\alpha = 0.05$. According to the standard deviation established for the Femoral neck bone mineral content (BMC) in a previous study (Bristow et al., 2019) and a estimated error of 0.04 g, a valid sample size of 30 was needed for a confidence interval of 95%.

Fig. 1. Experimental design.



5.3.3. Ethics approval and consent to participate

The study obtained approval CE052002 from the Catholic University of Murcia ethics committee on research, in accordance with the Declaration of Helsinki. All patients signed written informed consent forms prior to participating in the study.

5.3.4. Variables and instruments

The same researchers performed all the measurements in a single session between 8:00 and 14:00 h. The participants were examined barefoot with the temperature of laboratory standardized at 24 °C. Before the test measurement, the participants did not perform warm-up or stretching exercises. There was a 5-minute rest between measurements.

5.3.4.1. *Mediterranean diet adherence*

The prevention with mediterranean diet (PREDIMED) questionnaire was used, an instrument for dietary evaluation that provides information on the Mediterranean diet adherence (MDA) of older adults, which was previously validated in the Spanish population (Schröder et al., 2011).

5.3.4.2. *Physical activity level*

The Global Physical Activity Questionnaire (GPAQ) is a modified version of the International Physical Activity Questionnaire (IPAQ) and was developed by the World Health Organization (WHO) (de la Cámara et al., 2020). This questionnaire classifies participants according to activity level as the main objective of physical activity measurement and allows for the study of trends and associations with other types of behaviour or health outcomes.

5.3.4.3. *Kinanthropometric measurements*

Kinanthropometric parameters were measured based on the standards of the International Society for the Advancement on Kinanthropometry (ISAK) (Esparza-Ros et al., 2019). Weight (kg) was evaluated in light clothing without footwear by using an electronic scale (Seca 877, Birmingham, UK), and height (cm) was measured using a stadiometer (Seca 763, Birmingham, UK).

5.3.4.4. *Blood parameters*

Blood parameters (BP) were measured following the recommendations for older patients (Benetos et al., 2019). Systolic blood pressure (SBP), diastolic BP (DBP), and pulse rate (PR) were measured using a calibrated automatic arm device

(OMRON, model HEM-7113). The final value for BP, SBP and DBP was the mean of two recordings with three minutes apart.

Finger stick blood samples were collected before 9-h. The Afinion™ Analyzer (Alere, Ltd., Stockport, UK) device was used for the lipid panel test. This test measured total cholesterol (Chol), High-Density Lipoprotein cholesterol (HDL), Low-Density Lipoprotein cholesterol (LDL), Triglycerides (Trig), Non-HDL Lipids (LipidNonHDL) and the Chol/HDL ratio in whole blood, serum and plasma to be used in the diagnosis and treatment of lipid disorders.

5.3.4.5. *Densitometry measurements*

Bone mineral content (BMC), bone mineral density (BMD) and body composition were measured with Dual energy X-ray absorptiometry (DXA) (QDR 4500A, fan-beam densitometer, Hologic, Waltham, MA, USA). This method is used for body composition measurements for the evaluation of soft tissue composition, fat mass (FM), lean mass and total mass (Bi et al., 2018). The variables measured included: Spine BMC and BMD; Femoral neck BMC and BMD; FM/Height; Lean mass/Height; Total and percentage FM; and Total and percentage trunk FM.

5.3.4.6. *Muscle strength measurement*

To measure muscle strength, the participants performed two tests:

Handgrip strength test (HG). HG was measured in a standing position with the arms at the sides. The participants performed one repetition in each hand to familiarize themselves with the device and the test. Each participant was asked to squeeze the grip with maximal strength for 3 s with the right hand. The highest peak strength (kg) recorded between the three attempts was considered for analysis. A digital grip strength dynamometer was used for this (TKK 5401; Takei Scientific Instruments Co., Ltd., Tokyo, Japan).

To determine the maximal isometric knee extension (IKE) strength, the participants were assessed while seated with a knee and hip angle of 90°. Participants seated in a chair were instructed to push as strong as possible for three seconds while provided with verbal encouragement. The extension test was assessed with a force transducer (Musclelab, Ergotest, Norway) sampling at 1000

Hz. The subjects performed three IKE tests with 2 min of rest between tests. The maximum peak force in Newton (Nm) was collected.

5.3.5. Statistical analysis

The Kolmogorov–Smirnov test and Mauchly's W-test were used to evaluate the normality and the sphericity of the data. The mean and standard deviation were calculated from the quantitative variables, and frequency and percent were used for the qualitative variables. The participants were categorized as having a healthy lifestyle (HL) or unhealthy lifestyle (UL). HL was considered to be those who complied with at least 300 min of moderate to vigorous physical activity (MVPA) (WHO extended recommendation to achieve greater benefits than the recommended 150 min), and who maintained a MDA (above 9 points, calculated according to the mean and median of the sample) vs UL, those who did not comply with either or both parameters. Analysis of covariance (ANCOVA) using to comparing the change from baseline between groups. This analysis was performed unadjusted and adjusted by age as in previous research studies (Marcos-Pardo et al., 2020). A two-way ANOVA with repeated measures in 1 factor (time) was used to analyze inter- and intra-group differences. An error of $p \leq .05$ was established. The statistical analysis was performed using the statistical package SPSS 21.0 for Windows.

5.4. RESULTS

A total of 40 women volunteered for the study. Two women were eliminated for not meeting the inclusion and exclusion criteria. Thirty eight women were included in the study and were measured at pretest. All of them were contacted to attend the post-test. Three women were infected with Covid at the time of the post-test and 5 women were reluctant to come forward to those detected for fear of contracting Covid. Thirty women attended the post-test and are analyzed in this study.

Table 1 show the characteristics of the sample. The sample consisted of Spanish women between 60 and 70 years old. More than 50% of them were married, retired, and with an educational level corresponding to elementary school.

Approximately three-quarters of them lived with a partner, and two out of three had an UL.

Table 1. Characteristic of the sample.

Variable	%(n) or X±SD
Age (year-old)	64.43±4.58
Height (cm)	154.15±7.49
Body mass (kg)	71.27±12.60
Marital status	
Single	6.67 (2)
Married	56.67 (17)
Separated	6.67 (2)
Widow	30 (9)
Occupation	
Full-Time Worker	13.33 (4)
Part-Time Worker	6.67 (2)
Unemployed	20 (6)
Retired	60 (18)
Education level	
No education	13.33 (4)
Elementary school	56.67 (17)
High school	16.67 (5)
Bachelor's Degrees or higher	13.33 (4)
Living status	
Living with someone	73.33 (22)
Living alone	26.67 (8)
Lifestyle (Active and Mediterranean diet adherence vs non-active or no adherence)	
Healthy	30 (9)
Unhealthy	70 (21)

Table 2 shows that LDL increased ($+10.30 \pm 3.19$; $p = .003$), HDL decreased (-7.01 ± 1.78 ; $p = .001$), Non-HDL lipids increased ($+8.73 \pm 3.02$; $p = .007$), Chol/HDL lipids increased ($+0.42 \pm 0.08$; $p < .001$), femoral neck BMD decreased (-0.02 ± 0.01 ; $p = .017$), percent FM/height increased ($+0.37 \pm 0.10$; $p = .002$), total FM (kg) increased ($+0.81 \pm 0.24$; $p = .002$), percent FM (%) increased ($+0.67 \pm 0.21$; $p = .003$), total trunk

FM (kg) increased ($+0.53 \pm 0.20$; $p = .013$), percentage trunk FM (%) increased ($+1.06 \pm 0.33$; $p = .003$), HG decreased ($- 0.87 \pm 0.36$; $p = .023$) and IKE decreased ($- 302.80 \pm 24.14$; $p < .001$) after the lockdown, significantly. When these changes were adjusted by age values are maintained.

Table 3 shows the changes before and after lockdown according to HL and UL. The HL group showed a decrease in HDL ($- 6.85 \pm 3.04$; $p = .033$), increase in Chol/HDL lipids (0.29 ± 0.11 ; $p = .012$), increase trunk FM (1.16 ± 0.51 ; $p = .032$) and decrease in IKE ($- 303.06 \pm 41.90$; $p < .001$), significantly. The UL group showed a increased BMI (0.41 ± 0.16 ; $p = .015$), and increased LDL ($+13.76 \pm 3.33$; $p < .001$), decreased HDL ($- 6.91 \pm 1.87$; $p = .001$), increased Non-HDL lipids ($+14.15 \pm 3.02$; $p < .001$), increased Chol/HDL lipids ($+0.51 \pm 0.07$; $p < .001$), decreased femoral neck BMD ($- 0.02 \pm 0.01$; $p = .009$), increased FM/height (%) ($+0.46 \pm 0.11$; $p < .001$), increased trunk FM (kg) ($+0.52 \pm 0.22$; $p = .024$), increased trunk FM (%) ($+1.04 \pm 0.32$; $p = .003$), increased total FM (kg) ($+1.05 \pm 0.26$; $p < .001$), increased total FM (%) ($+0.87 \pm 0.21$; $p < .001$), decreased HG ($- 0.80 \pm 0.38$; $p = .046$) and decreased IKE ($- 304.29 \pm 25.75$; $p < .001$), significantly. No differences were observed between groups in the pre-post lockdown change.

Table 2. Effect of lockdown due to Covid pandemic (Unadjusted and adjusted by age).

Variable	Pre-test (M±SD)	Post-test (M±SD)	Unadjusted			Adjusted by age		
			Difference post-pre (M±SD)	p	95% CI (Mpost-Mpre)	Difference post-pre (M±SD)	p	95% CI (Mpost-Mpre)
BMI (kg/m ²)	29.97±4.54	30.25±4.67	0.28±0.16	.097	-0.05;0.61	0.26±0.15	.097	-0.05;0.56
BP (mmHg)	97.43±11.16	95.5±11.29	-1.89±2.22	.403	-6.43;2.67	-2.00±2.24	.38	-6.59;2.6
SBP (mmHg)	132.37±21.61	130.03±19.89	-2.46±4.84	.616	-12.40;7.48	-2.70±4.89	.585	-12.74;7.34
DBP (mmHg)	79.97±10.13	78.23±10.79	-1.60±1.62	.332	-4.2;1.72	-1.64±1.65	.327	-5.03;1.74
PR (bpm)	68.87±11.63	66.03±11.24	-2.52±1.52	.11	-5.64;0.61	-2.48±1.55	.121	-5.67;0.7
Chol (mg/dL)	190.1±29.44	195.7±24.53	1.73±3.99	.669	-6.47;9.92	1.50±4.01	.712	-6.75;9.75
LDL (mg/dL)	101.79±25.82	114.13±20.42	10.30*±3.19	.003	3.76;16.84	10.07*±3.17	.004	3.55;16.58
HDL (mg/dL)	66.17±12.61	60.27±12.96	-7.01*±1.78	.001	-10.67;-3.35	-6.88*±1.78	.001	-10.54;-3.23
Trig (mg/dL)	110.72±58.83	106.3±41.82	-8.30±10.95	.455	-30.75;14.16	-8.93±10.99	.424	-31.53;13.66
LipidNonHDL (mg/dL)	123.93±24.01	135.43±20.09	8.73*±3.02	.007	2.55;14.92	8.38*±2.87	.007	2.48;14.28
Chol/HDL (mg/dL)	2.92±0.49	3.35±0.59	0.42*±0.08	<.001	0.26;0.57	0.40*±0.06	<.001	0.27;0.53
Spine BMC (Kg)	1.82±0.27	1.83±0.26	2.95±9.71	.763	-16.97;22.88	2.55±9.83	.798	-17.66;22.76
Spine BMD (g/cm ²)	1.03±0.08	1.03±0.09	-0.00±0.00	.756	-0.01;0.01	-0.00±0.00	.796	-0.01;0.01
Femoral neck BMC (g)	3.14±0.78	3.15±0.79	0.02±0.03	.634	-0.05;0.08	0.02±0.03	.612	-0.05;0.08
Femoral neck BMD (g/cm ²)	0.7±0.1	0.69±0.11	-0.02*±0.01	.017	-0.03;-0.00	-0.02*±0.01	.02	-0.03;0.00
FM / Height (%)	13.71±3.34	14.1±3.4	0.37*±0.10	.002	0.15;0.58	0.36*±0.11	.002	0.15;0.58
Lean mass / Height (kg/m ²)	14.84±1.42	14.81±1.5	-0.02±0.10	.817	-0.24;0.19	-0.05±0.08	.58	-0.21;0.12
Trunk FM (kg)	16.09±4.15	16.59±4.15	0.53*±0.20	.013	0.12;0.95	0.54*±0.21	.015	0.11;0.96
Trunk FM (%)	46.2±4.95	47.23±4.52	1.06*±0.33	.003	0.38;1.73	1.10*±0.30	.001	0.49;1.72
Total FM (kg)	32.66±8.70	33.54±8.78	0.81*±0.24	.002	0.32;1.31	0.81*±0.25	.003	0.30;1.31

Total FM (%)	46.24±4.43	46.98±4.25	0.67*±0.21	.003	0.25;1.09	0.69*±0.20	.002	0.29;1.1
HG (kg)	23.56±5.68	22.78±5.13	-0.87*±0.36	.023	-1.60;-0.13	-0.85*±0.36	.027	-1.6;-0.11
IKE (Nm)	548.02±167.46	248±68.91	-302.80*±24.14	<.001	-352.34;-253.26	-303.67*±24.50	<.001	-354.03;-253.32

Abbreviations: BMI = body mass index; BMC = bone mineral content; BMD = bone mineral density; BP = blood pressure; bpm = beats per minute; DBP = diastolic blood pressure; FM = fat mass; HDL = high density lipoprotein; HG = Handgrip; IKE = Isometric knee extension strength; LDL = low density lipoprotein; MBP = mean blood pressure; mmHg = millimetres of mercury; Nm = newton meter; PR = pulse rate; SBP = systolic blood pressure; Chol = total cholesterol; Trig = triglycerides.

Table 3. Effects of lockdown according to healthy or unhealthy lifestyle + Time*Group Interaction (all age-adjusted).

Variable		Pre-test (M±SD)	Post-test (M±SD)	Adjusted by age		Group * time interaction		
				Difference post-pre (M±SD)	p	95% CI (Mpost-Mpre)	F	Sig
BMI (kg/m2)	HL	30.65±4.64	30.73±4.96	0.11±0.26	.682	-0.42;0.63	1.008	.328
	UL	29.67±4.57	30.05±4.65	0.41*±0.16	.015	0.09;0.73		
BP (mmHg)	HL	96.22±13.8	96.63±12.82	-1.19±3.83	.758	-9.06;6.67	0.127	.724
	UL	97.95±10.17	95.02±10.88	-2.8±2.35	.244	-7.63;2.03		
SBP (mmHg)	HL	129.78±20.3	130.56±16.71	-2.03±8.36	.81	-19.21;15.15	0.018	.893
	UL	133.48±22.55	129.81±21.49	-3.37±5.14	.518	-13.93;7.19		
DBP (mmHg)	HL	79.44±15.38	79.67±16.02	-0.77±2.81	.786	-6.56;5.01	0.276	.604
	UL	80.19±7.35	77.62±8.05	-2.52±1.73	.158	-6.07;1.04		
PR (bpm)	HL	68.56±10.42	65.89±8.96	-2.03±2.65	.451	-7.47;3.42	0.086	.772
	UL	69±12.35	66.1±12.28	-2.94±1.63	.082	-6.29;0.41		
Chol (mg/dL)	HL	198.88±33.69	200.33±26.39	-4.24±6.87	.542	-18.35;9.87	2.013	.168
	UL	186.76±27.81	193.71±24.09	7.23±4.22	.098	-1.44;15.91		
LDL (mg/dL)	HL	105.12±26.43	114.44±16.44	6.37±5.42	.251	-4.78;17.52	1.34	.258
	UL	100.52±26.13	114±22.28	13.76*±3.33	<.001	6.91;20.62		
HDL (mg/dL)	HL	72.13±15.39	67.56±17.71	-6.85*±3.04	.033	-13.11;-0.60	0.000	.987
	UL	63.9±10.95	57.14±9.16	-6.91*±1.87	.001	-10.76;-3.07		
Trig (mg/dL)	HL	108.25±54.67	90.78±29	-19.94±18.8	.299	-58.59;18.70	0.988	.329
	UL	111.67±61.61	112.95±45.22	2.07±11.55	.859	-21.68;25.82		
LipidNonHDL (mg/dL)	HL	126.75±25.68	132.78±18.55	2.61±4.91	.599	-7.48;12.71	3.976	.057
	UL	122.86±23.91	136.57±21.04	14.15*±3.02	<.001	7.95;20.35		
Chol /HDL (mg/dL)	HL	2.81±0.51	3.1±0.67	0.29*±0.11	.012	0.07;0.52	2.913	.1
	UL	2.96±0.49	3.46±0.53	0.51*±0.07	<.001	0.38;0.65		
Spine BMC (Kg)	HL	1.82±0.25	1.82±0.24	-4.43±16.82	.794	-39.00;30.14	0.496	.488
	UL	1.82±0.28	1.83±0.28	9.53±10.34	.365	-11.72;30.77		
Spine BMD (g/cm²)	HL	1.03±0.09	1.02±0.09	-0.00±0.01	.934	-0.02;0.01	0.013	.909

	UL	1.03±0.08	1.03±0.09	-0.00±0.00	.722	-0.01;0.01		
Femoral neck BMC (g)	HL	3.21±0.56	3.19±0.57	0.01±0.05	.851	-0.10;0.12	0.036	.852
	UL	3.11±0.87	3.13±0.88	0.02±0.03	.509	-0.05;0.09		
Femoral neck BMD (g/cm²)	HL	0.7±0.08	0.69±0.1	-0.01±0.01	.252	-0.03;0.01	0.219	.644
	UL	0.7±0.11	0.68±0.11	-0.02*±0.01	.009	-0.03;-0.01		
FM / Height (%)	HL	14.24±3.21	14.48±3.57	0.27±0.18	.152	-0.10;0.64	0.816	.375
	UL	13.49±3.45	13.94±3.4	0.46*±0.11	<.001	0.23;0.69		
Lean mass / Height (kg/m²)	HL	14.94±1.63	14.9±1.72	-0.09±0.14	.506	-0.38;0.19	0.346	.561
	UL	14.8±1.36	14.78±1.44	0.00±0.09	.976	-0.17;0.18		
Trunk FM (kg)	HL	16.59±4.66	17.05±5.44	0.55±0.35	.127	-0.17;1.27	0.007	.934
	UL	15.87±4.02	16.39±3.62	0.52*±0.22	.024	0.08;0.96		
Trunk FM (%)	HL	47.07±3.47	47.93±4.41	1.16*±0.51	.032	0.11;2.22	0.039	.844
	UL	45.82±5.5	46.92±4.64	1.04*±0.32	.003	0.39;1.69		
Total FM (kg)	HL	33.91±9.99	34.39±10.58	0.56±0.42	.196	-0.31;1.42	0.998	.327
	UL	32.13±8.31	33.17±8.15	1.05*±0.26	<.001	0.52;1.59		
Total FM (%)	HL	47.14±3.81	47.52±4.34	0.51 ± 0.34	.139	-0.18;1.21	0.806	.378
	UL	45.85±4.71	46.75±4.3	0.87 ± 0.21*	<.001	0.45;1.30		
HG (kg)	HL	23.12±5.36	22.35±5.73	-0.91 ± 0.62	.157	-2.18;0.37	0.021	.886
	UL	23.75±5.92	22.97±4.99	-0.80 ± 0.38*	.046	-1.59;-0.02		
IKE (Nm)	HL	534.05±148.7	246.51±64.51	-303.06 ± 41.90*	<.001	-389.19;-216.93	0.001	.98
	UL	554.01±178.02	248.64±72.25	-304.29 ± 25.75*	<.001	-357.23;-251.36		

Abbreviations: BMC = bone mineral content; BMD = bone mineral density; BMI = body mass index; BP = blood pressure; bpm = beats per minute; DBP = diastolic blood pressure; FM = fat mass; HDL = high density lipoprotein; HG = Handgrip; HL=healthy lifestyle; IKE = Isometric knee extension strength; LDL = low density lipoprotein; MBP = mean blood pressure; mmHg = millimeters of mercury; Nm = newton meter; PR = pulse rate; SBP = systolic blood pressure; Chol = total cholesterol; Trig = triglycerides; UL= unhealthy lifestyle.

5.5. DISCUSSION

The main objective of this study was to analyze the effects of 13-week period of lockdown due to COVID-19 on different health parameters: physical activity level, Mediterranean diet adherence, anthropometric measurements, blood parameters, densitometry parameters and muscle strength levels of women aged 60–70 years. The results showed that blood HDL, LDL and Non-HDL lipid values worsened after lockdown, with a significant increase in LDL and a decrease in HDL, as in previous studies (Perrone et al., 2021). In addition, in the present study, a significant worsening of HDL and cholesterol/HDL lipid values was observed in individuals who had a HL and UL due to the lockdown, but those who had an UL also presented a worsening LDL, and Non-HDL lipid values. Therefore, maintaining a healthy lifestyle during the lockdown period, including physical activity and a healthy diet, could decrease the negative effects of habit changes on blood parameters during lockdown (Alfie et al., 2021; Perrone et al., 2021). These changes in daily life may increase the risk of developing heart disease in the long term (Alfie et al., 2021), with this being especially relevant in the population of the present investigation as they are adult and older women; thus, age should be taken into consideration as it increases the predisposition to cardiovascular disease (Alfie et al., 2021).

Regarding blood pressure, SBP significantly increased with age. This may pose a risk, as a high SBP associated with age has been associated to the possible occurrence of major cardiovascular disease events, coronary heart disease, stroke, and heart failure in other studies (Ettehad et al., 2016). In contrast, no significant changes were found in SBP, DBP or BP pre and post lockdown. Furthermore, differences were not found between HL and UL. The lack of changes may be due to the average time period elapsed (Veloudi & Sharman, 2018).

The present investigation also found a significant increase in trunk FM (absolute and percentage), total FM (absolute and percentage), and FM/height percentage after lockdown, in line with previous studies (Karatat et al., 2021). Considering that in the adult and older population, height does not usually change in the short term (Mahoney et al., 2018), the increase in FM/height percentage could be due to the changes found in FM. Previous studies have shown that lockdown

led to a decrease in the level of physical activity or a worsening of eating habits, including a higher frequency of snacking, with these factors affecting the female gender to a greater extent (Ghosh et al., 2020). Not surprisingly, in the present study, it was found that those with an UL were women who showed the greatest significant increase in the variables related to total and trunk fat accumulation and increased significantly in BMI as well. Another possible explanation could be that there was an increase in total FM and trunk FM with age (Coin et al., 2012). The area of fat mass distribution is a factor to consider, as total FM has been correlated with different levels of cardiometabolic risk, as well as trunk FM, which is associated with a high risk of cardiovascular disease (Coin et al., 2012). Therefore, in light of the results of the present study, older women who have an UL would have a higher probability of suffering from this type of pathologies.

Regarding bone mass, in general no differences were found when comparing the pre-post lockdown variables. However, when dividing the women according to their lifestyle, a significant decrease in femoral neck BMD was found in those with an UL. These changes in normal (nonlockdown) situations may be due to multiple reasons, including genetics, some types of medication, other diseases, nutrition and lifestyle (Ferrari & Rizzoli, 2005). With respect to the latter, it is worth noting that lifestyle was one of the most affected factors during the lockdown (Scarmozzino & Visioli, 2020). The first cause may be physical inactivity and a sedentary lifestyle (Umeda-Raffa et al., 2021). Disuse or prolonged periods of inactivity such as lockdown or the absence of stimulus on the skeleton, favor the reduction of bone mass, making it more fragile, while subjecting it to a mechanical load through exercise increases bone mass (Umeda-Raffa et al., 2021). On the other hand, home lockdown reduced exposure to the sun over a long period of time (Umeda-Raffa et al., 2021), thus affecting vitamin D synthesis, and therefore negatively affecting calcium absorption in the intestine, the maintenance of adequate levels of calcium and phosphate for optimal bone formation, and the promotion of proper functioning of the parathyroid hormone, which maintains serum calcium levels (Umeda-Raffa et al., 2021). For these reasons, the sum of these factors may have been the main cause for the reduced BMD observed in the population with an UL.

Another objective of this study was to test the effects of lockdown on muscle strength production capacity. We found a significant worsening of the results

obtained in the IKE test by both groups after the lockdown. These results are in agreement with those expected, due to the effect of age on the decrease in the capacity to produce strength (Kirwan et al., 2020), in addition to a situation of restricted mobility and, therefore, a decrease in physical activity (Shur et al., 2021). On the other hand, only the UL older women showed a significantly worsening HG test results. This may be due to the maintenance of the active lifestyle by the HL older women, whereas the UL older women were able to greatly reduce their daily physical activity during the lockdown than post lockdown due to the restrictive mobility policies. This may be because the muscle response to inactivity is stronger than to physical activity (Shur et al., 2021). The loss of muscle strength, in addition to the absence of significant differences in the Lean mass/Height variable, reinforces the idea found in previous research, where it was observed that the magnitude of strength loss observed due to aging and inactivity was greater than the degree of muscle mass loss (Shur et al., 2021). Therefore, it could be said that age, inactivity, and an UL during lockdown, promoted the loss of muscle strength in the population studied.

The main strength of the present research was the combined study of physical, lifestyle and physiological parameters during this period, with a longitudinal study which included a field test to analyze the effects of lockdown on the health of older women. Therefore, the data collected in the present study could be very useful in similar, future situations to predict the changes in health variables in this population group, as well as to improve the health management system by political entities. On the other hand, more research will be necessary, especially in the most affected or at-risk groups, in this case on their health in relation to physical activity and lifestyle. Regarding the limitations encountered, the post-lockdown measurements could not be performed until the mobility restrictions imposed allowed the sample to access the center where tests were performed, as well as the absence of a control group that was not in lockdown.

As conclusion, it was observed that lockdown had a great negative impact on Spanish older women in most of the measured parameters: cholesterol, femoral neck BMD, FM and strength values. In addition, it was found that a HL could be a protective factor against the age-associated increase in LDL, decrease in HDL, increase in FM, and decrease strength values. These results should be taken into account due to the potentially large negative impact on public health that a

situation of lockdown and social isolation such as the one experienced could have, so that non-pharmacological strategies such as physical exercise and a healthy diet are deemed necessary to ensure the health of individuals during possible future lockdown situations. Furthermore, it is crucial to highlight the need for future studies investigating not only the impact of COVID-19 lockdown restrictions on health and muscle strength parameters, but also the short- and long-term effects of specific interventions that aim to improve overall health and include a home-tailored physical exercise program.

**ESTUDIO 2: SAGITTAL SPINE
DISPOSITION AND PELVIC TILT
DURING OUTDOOR FITNESS
EQUIPMENT USE AND THEIR
ASSOCIATIONS WITH
KINANTHROPOMETRY PROPORTIONS
IN MIDDLE-AGED AND OLDER
ADULTS**

Vb - ESTUDIO 2 - Sagittal Spine Disposition and Pelvic Tilt During Outdoor Fitness Equipment Use and Their Associations With Kinanthropometry Proportions in Middle- Aged and Older Adults

5.6. ABSTRACT

Background. Outdoor fitness training has become popular as a tool for improving the health, especially middle-aged and older adults. For this purpose, outdoor fitness equipment (OFE) have been installed in public areas. However, their safety and effectiveness are still unknown. The aim of the present research was to analyze the sagittal disposition of the spine and pelvic tilt during the use of OFE, and to determine the influence of anthropometric variables on these factors in middle-aged and older adults.

Methods. Seventy healthy volunteers, 56 women and 14 men (age: 63.14 ± 8.19 years) participated in the study. Sagittal spine disposition and pelvic tilt were measured using a Spinal Mouse®, in the relaxed standing position, and during the use of the OFE. In addition, kinanthropometry variables were also measured according to the guidelines of the International Society for the Advancement of Kinanthropometry.

Results. Regarding thoracic kyphosis, a significant decrease was found in thoracic kyphosis in the initial position (IP) in single bonny rider (SBR) ($p = .006$) and row ($p = .046$), and a significant increase in the final position (FP) in the row ($p = .011$), surfboard ($p < .001$) and air walker ($p = .027$) machines. In relation to the lumbar curvature and pelvic tilt, a significant decrease in lumbar lordosis and a decrease in pelvic anteversion were observed in the IP and FP in SBR and row; and in the bike ($p < .001$) machine. In the surfboard machine, a significant decrease in lumbar lordosis was found ($p = .002$), with no changes in pelvic tilt. According to the multiple linear regression analysis, the subjects with a higher cormic index and height were more at risk of increasing their thoracic kyphosis, decreasing lumbar lordosis and/or decreasing pelvic anteversion towards pelvic retroversion.

Conclusions. Middle-aged and older adults show spinal misalignments when using the OFE with respect to the standing position, showing a decrease in the thoracic kyphosis in IP of SBR and ROW, and a significant increase in the surfboard

and air walker, and in the FP of Row, in the lumbar lordosis in all the OFE in sitting and some in standing, and in the pelvic anteversion in all the OFE in sitting. The variables height and the cormic index explained most of the changes in sagittal spine disposition.

5.7. INTRODUCTION

Ergonomics is understood as the part of biomechanics that works on the adaptation of machinery and workplaces to optimize them for the safety and efficiency of users (Georgoulas et al., 2014; Signorile et al., 2017). For this purpose, machines and furniture are adapted to the body proportions of the subjects for whom they are destined (Castellucci et al., 2016; Rojas et al., 2013). Among these machines, we find the ones used for guided bodybuilding exercises, which are very common in fitness centers (Cardozo et al., 2019; Ribeiro et al., 2020; Signorile et al., 2017).

These strength training machines are designed to be effective and safe for users (Chow, 2013; Chow & Wu, 2019; Coratella et al., 2019). In this way, the machinery is designed so that during sports practice the position of the body is optimal for the desired muscular action, without causing alterations in the rest of the body structures or in the work itself (Coratella et al., 2019; Maffiuletti & Lepers, 2003; Rodríguez-Ridao et al., 2020).

A lack of ergonomics or improper use of weight training machines during training can be detrimental to the health of the person performing the exercise, and can also cause changes in the maximum strength-producing capacity of the user by modifying biomechanics. More specifically, the execution of exercises with an excessive range of motion and the adoption of inadequate postures, especially with regard to the spine, or an incorrect execution of the exercise performed (Chow, 2013; Rodríguez-Ridao et al., 2020), together with an increase in the loads during execution can lead to multiple injuries of different kinds (Hartmann et al., 2013; McGill et al., 2014; Sayers et al., 2020). Among the most frequent injuries that could result from overloading caused by incorrect use of this type of machinery we find herniated discs, spondylolysis, and spondylolisthesis (Harrison et al., 2005). However, the origin of injuries and pathologies of both the spine and the adjacent muscular system is multifactorial, so other factors such as technique, fatigue,

sarcopenia or age must also be taken into consideration (Gottschlich & Young, 2011; Montero-Fernández N & Serra-Rexach., 2013; Ohyama et al., 2019).

To avoid these situations of lack of ergonomics or improper use of weight training machines during training, as well as the most frequent related injuries (Ailon et al., 2015; Harrison et al., 2005), the vast majority of weight training machines on the market today are adjustable. In this way, they can be adapted to each user, regardless of their anthropometric characteristics and proportions, while maintaining efficiency and safety when training with them. In addition, as they are mostly guided machines, the muscles involved can be worked in a controlled range of motion (Ribeiro et al., 2020), which reduces the risk of compensations in other structures. This type of compensation occurs especially in frail subjects with postural deviations or previous spinal injuries, as is the case in middle-aged and older adults (Ribeiro et al., 2020). More specifically, previous studies have found that the older population tends to show thoracic hyperkyphosis, reductions in lumbar curvature and intervertebral disc degeneration (Ailon et al., 2015; Ohyama et al., 2019). Recent systematic reviews (Bayattork et al., 2020) and systematic reviews with meta-analysis (González-Gálvez et al., 2019) have proven that systematic strength training can lead to improvement in the sagittal spinal curvatures, or correct malalignments, therefore, it would be a highly recommended training in this population (Ohyama et al., 2019; Toprak & Özer, 2017).

Despite this evidence, most studies that have analyzed the adaptations that occur in the sagittal spine disposition with the systematic practice of exercise have focused on specific sports in athletes of different categories (Grabara, 2018; López-Miñarro et al., 2017) or certain types of physical exercise in older (Grabara & Szopa, 2015). However, few studies have analyzed the acute influence of physical exercise on the sagittal spine disposition during the use of specific sports equipment. More specifically, the sagittal spine disposition has been analyzed in kayakers or canoeists who were paddling in the boat (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2012). or in cyclists when they were standing on the bike (Muyor, 2015; Muyor et al., 2011). However, there are no studies that have analyzed the adaptations that occur in the sagittal spine disposition during the use of sports fitness equipment such as gym equipment.

Due to the benefits observed from training with weight training machines such as strength and functional fitness gains, as well as increase in hormones of

bone formation in those who use them, especially in older adults (Cardozo et al., 2019; Moghadasi & Siavashpour, 2013), the installation and use of outdoor fitness equipment (OFE) areas as a tool for the improvement of the health of the population, especially middle-aged and older adults, has been popularized by different governmental institutions (Cohen et al., 2012). OFE are outdoor sports facilities commonly located in public places, composed of machines that seek to have a certain similarity with the weight training machines found in sports centers. However, this type of equipment, unlike the equipment used in fitness rooms, is not adjustable, and no studies have been found that have analyzed the sagittal disposition of the spine when using this type of machinery, or the influence that anthropometric proportions could have on them. Therefore, the aim of the present research was to analyze the sagittal disposition of the spine and pelvic tilt during the use of OFE, as well as to determine the influence of anthropometric variables on these factors in middle-aged and older adults. It was hypothesized that there would be changes in sagittal spine disposition and pelvic tilt during the use of OFE and that these changes would depend on anthropometric parameters related to structural bone characteristics in middle-aged and older people.

5.8. MATERIALS & METHODS

5.8.1. Participants

The data used in this cross-sectional study derives from the Intelligent Outdoor Fitness Equipment Project (Design and manufacture of new ergonomic, efficient and healthy outdoor fitness equipment with an application for mobile devices (APP) to assess and control training); code: RTC-2017-6145-1, 2017; with a research grant from the Spanish Ministry of Science, Innovation and Universities.

The sample consisted of 70 healthy volunteers, 56 women and 14 men aged from 50 to 80 years old (mean age: 63.14 ± 8.19 years). The inclusion criteria were: (1) minimum age of 50 years and maximum age of 85 years; (2) functional independence; (3) not being part in a training program during the measurements; (4) not to have any pathology that would prevent the performance of the tests; (5) not having had an operation on the spine or hamstring musculature; and (6) not present a medically diagnosed structural spinal pathology such as a structured

thoracic hyperkyphosis, a structured lumbar hyperlordosis, or some kind of structured rectification, etc.

The sample size and power were established taking into account the standard deviation (6.67) of the thoracic curvature variable in a sample with similar characteristics ($n = 42$) (Hasegawa et al., 2018). The sample size of this study was 70 subjects, with a power of 95% and a significance level of .05; an estimated error of 1.56° was found. Rstudio 3.15.0 software was used to determine the sample size.

The study was conducted in accordance with the Declaration of Helsinki, and was approved by the institutional ethical committee of the Catholic University of Murcia (Ethical Application Ref: CE111908). This study was designed following the Strobe Statement (von Elm et al., 2008). All participants were informed about the tests to be performed in this study and signed an informed consent form before the measurements.

5.8.2. Measurements

The same trained researcher measured the participants in a single session between 09:00 and 11:00 h. The laboratory temperature was standardized at 24 °C. The participants were instructed to wear lightweight clothes. Participants had not previously exercised on the same day of the assessment and at least two hours had passed since they had been in the supine position (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015).

5.8.3. Sagittal spine disposition and pelvic tilt

The sagittal spine disposition and pelvic tilt were measured using the Spinal Mouse® system (Idiag, Fehralt Dorf, Switzerland). Measurements were taken randomly in the relaxed standing position and using the OFE. In the OFE with a cyclic movement, the measurements were taken at the starting position, defining this as the position when the participant was on the OFE, but before starting the movement for which it is intended.

In the acyclic OFE, the measurement was made in the same conditions as the cyclic ones, considering this position as the initial position (IP). After that, the subject was asked to execute the movement for which the OFE was designed at a

controlled speed until reaching the end of the concentric phase in the OFE. The participant had to maintain this final position (FP) for the sagittal spine disposition to be assessed. Since, the way OFE is used could influence the disposition in it (Chow & Wu, 2019), in the present investigation each OFE was used according to the manufacturer's recommendations. More specifically, in the air walker the participant did a reverse stride, standing facing forward on the OFE, grasping the front; in the Bike the participant was sitting on the OFE, with one foot on each pedal, hands on the handgrip and crank parallel to the ground; in the surfboard the participant was standing on the platform grasping both sides; in the SBR the participant also was sitting on the seat, with feet on the support, and grasping the handgrip with hand supine, pull with arms to 90° elbow flexion; and in the Row the participant was sitting on the seat, grasping the handgrip with hands about shoulder width apart, and feet on the supports, pull on the handgrip to 90° elbow flexion. The outdoor fitness pieces of equipment were obtained from the company Entorno Urbano S.L.U (Murcia, Spain) (Fig. 1).

Figure 1. Outdoor fitness equipment.



Each position was performed twice, and the final value of each measurement was the mean of both measurements. Five minutes were left between the different positions to avoid acute adaptations to the maintenance of a given position in an isometric manner following the methodology of previous studies (López-Miñarro et al., 2017). For thoracic and lumbar curvatures, a positive value indicated that the

curve was kyphotic, while a negative value indicated that the curve was lordotic. For pelvic tilt, a positive value indicated that the presence of pelvic anteversion, while a negative value indicated the presence of pelvic retroversion.

5.8.4. Kinanthropometry

The measurements were taken according to the guidelines of the International Society for the Advancement of Kinanthropometry (Esparza-Ros et al., 2019) by an accredited anthropometrist. The measurements taken were body mass, stretch stature, sitting height, waist and hip girths, arm and forearm length, and biacromial and biiliocrystal breadths. A Tanita BC-545N scale (Tanita, Arlington Heights, Illinois, USA) was used to measure body mass, and a HR001 portable stadiometer (Tanita, Arlington Heights, Illinois, USA) was used to measure stretch stature and sitting height. The lengths were taken with a Pro model segmometer (Cescorf Ltd., Porto Alegre, Brazil), and breadths with a large sliding caliper (Cescorf Ltd., Porto Alegre, Brazil). Each measurement was taken twice or three times if the difference between the first two measurements was greater than 1%, taking the mean or median, respectively. With the measurements taken, the BMI ($\text{weight}/(\text{Height(m)}^2)$), cormic index ($((\text{sitting height}/\text{height}) \times 100)$), waist-hip ratio ($\text{Waist girths}/\text{Hip girths}$); cormic index; upper limb length (arm length + forearm length) and acromio-iliac index ($((\text{biiliac diameter}/\text{biacromial diameter}) \times 100)$) were calculated as previously described in Salces et al. (2007).

5.8.5. Statistical analyses

The Kolmogorov Smirnov test and Mauchly's W-test were used to evaluate the normality and the sphericity of the data. The mean and standard deviation were calculated, and to determine differences between each curvature in standing position and in each OFE, a *t*-test for correlated samples was used. The effect size was calculated by Cohen's *d* coefficient.

For this purpose, a value > 0.8 was considered a high effect; a value between 0.6 and 0.8 was considered a moderate-high effect; a value between 0.4 and 0.6 was considered a moderate effect; a value between 0.2 and 0.4 was considered a low-moderate effect; and a value < 0.2 was considered a low effect size (Cohen, 1988). An ANCOVA was performed to analyze the influence of sex and height in the

comparison of the differences between the position in standing and in the OFE. The effect size was calculated with partial eta squared (η_p^2). To determine the association between sagittal spine disposition and pelvic tilt during OFE use and kinanthropometry proportions Pearson's bivariate correlation coefficients were used. The established ranges of correlation were as follows: $r > 0.7$ for a high correlation, 0.5 - 0.7 for a moderate correlation, and < 0.5 for a low correlation.

5.9. RESULTS

Table 1 show the mean and standard deviation of the middle-aged and older adults in anthropometric basic measures, BMI, girths, lengths, breadths and proportionality variables, as well as the sagittal spine disposition in standing position, and during the use of the OFE. It was found that the sample presented normal BMI and waist-hip ratio values ($29.69 \pm 4.27 \text{ kg/m}^2$ and 0.90 ± 0.09 , respectively). With respect to the spine disposition, the thoracic curvature in standing position was $50.10 \pm 10.67^\circ$, the lumbar curvature was $-31.85 \pm 9.34^\circ$, and the pelvic tilt was $21.32 \pm 7.31^\circ$. In the OFE, thoracic curvatures were between $46.92 \pm 11.51^\circ$ to $53.79 \pm 10.59^\circ$; lumbar curvatures were between $-31.23 \pm 10.20^\circ$ to $4.82 \pm 9.47^\circ$; and pelvic tilt were between $-4.25 \pm 9.59^\circ$ to $22.42 \pm 8.39^\circ$. The differences in the sagittal spine disposition and pelvic tilt between the different OFE and the standing position is shown in the Table 2. Regarding thoracic kyphosis, a significant decrease was found in the IP in SBR ($p = .006$) and row ($p = .046$), and a significant increase in the FP in the row ($p = .011$), surfboard ($p < .001$) and air walker ($p = .027$) machines, with an effect size from low to moderate. In relation to the lumbar curvature and pelvic tilt, a significant decrease in lumbar lordosis and a decrease in pelvic anteversion were observed in the IP and FP in SBR and row; and in the bike ($p < .001$) machine, with an effect size from low to high. In the surfboard machine, a significant decrease in lumbar lordosis was found ($p = .002$), with a moderate effect size, with no changes in pelvic tilt.

Table 1. Characteristics of the participants.

Anthropometric variables	$X \pm SD$	Spine variables	$X \pm SD$
Body Mass (kg)	74.82±13.69	Standing Thoracic curv. (°)	50.10±10.67
Height (cm)	158.56±9.64	Standing Lumbar curv. (°)	-31.85±9.34
BMI	29.69±4.27	Standing Pelvic tilt (°)	21.32±7.31
Sitting height (cm)	82.68±4.99	SBR IP Thoracic curv. (°)	46.92±11.51
Cormic index	52.35±1.44	SBR IP Lumbar curv. (°)	-2.64±10.71
Waist girth (cm)	93.31±11.40	SBR IP Pelvic tilt (°)	11.22±8.50
Hip girth	104.60±9.90	SBR FP Thoracic curv. (°)	52.24±10.83
Waist-hip ratio	0.90±0.09	SBR FP Lumbar curv. (°)	-14.59±14.27
Arm length	31.48±2.27	SBR FP Pelvic tilt (°)	9.73±10.59
Forearm length	23.44±1.95	Row IP Thoracic curv. (°)	47.63±10.47
Upper limb length	54.95±4.03	Row IP Lumbar curv. (°)	4.82±9.47
Biacromial breadth (cm)	37.16±1.94	Row IP Pelvic tilt (°)	2.49±7.28
Biiliocrystal breadth (cm)	31.03±2.20	Row FP Thoracic curv. (°)	53.71±11.91
Acromio-iliac index	0.84±0.06	Row FP Lumbar curv. (°)	-3.65±14.74
		Row FP Pelvic tilt (°)	-4.25±9.59
		Bike Thoracic curv. (°)	48.02±11.68
		Bike Lumbar curv. (°)	-3.12±11.75
		Bike Pelvic tilt (°)	14.80±9.21
		Surfboard Thoracic curv. (°)	53.79±10.59
		Surfboard Lumbar curv. (°)	-26.49±12.75
		Surfboard Pelvic tilt (°)	22.42±8.39
		Air walker Thoracic curv. (°)	52.33±9.82
		Air walker Lumbar curv. (°)	-31.23±10.20
		Air walker Pelvic tilt (°)	19.92±8.17

BMI: Body mass index; curv: curvature; FP: Final position; IP: Initial position; MIS: maximal isometric strength; SBR: Single bonny rider.

Table 2. Analysis of the differences in the spine sagittal curvatures between the OFE and the standing position.

OFE-Position	Variable	Differences OFE-Standing					Model: Differences			Model: Differences		
							OFE-Standing x Sex			OFE-Standing x Height		
		<i>X ± DS</i>	<i>p</i>	<i>df</i>	<i>Effect size (d)</i>	<i>CI 95%</i>	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2
SBR IP	Thoracic curv. (°)	-3.18±9.00	.006	64	0.29	-5.47; -0.94	0.011	.919	.001	0.327	.576	.021
	Lumbar curv. (°)	29.21±12.27	<.001	64	2.91	26.08;32.26	0.909	.352	.043	0.066	.800	.003
	Pelvic tilt (°)	-10.13±9.39	<.001	64	1.27	-12.50; -7.76	0.225	.638	.005	5.098	.029	.108
SBR FP	Thoracic curv. (°)	2.14±8.95	.053	64	0.20	-0.03;4.46	0.393	.540	.026	0.202	.659	.013
	Lumbar curv. (°)	17.25±14.23	<.001	64	1.43	13.63;20.79	2.165	.157	.098	0.008	.928	.000
	Pelvic tilt (°)	-11.52±9.50	<.001	64	1.27	-14.00; -9.25	0.002	.966	.000	5.391	.025	.114
Row IP	Thoracic curv. (°)	-1.96±8.77	.046	64	0.23	-4.96; -0.04	0.033	.859	.002	0.044	.836	.003
	Lumbar curv. (°)	36.67±10.88	<.001	64	3.90	34.44;39.80	0.968	.337	.046	0.014	.908	.001
	Pelvic tilt (°)	-18.12±8.37	<.001	64	2.58	-20.68; -16.61	0.036	.850	.001	5.179	.028	.110
Row FP	Thoracic curv. (°)	2.76±12.43	.011	64	0.32	0.84;6.19	0.500	.490	.032	0.493	.493	.032
	Lumbar curv. (°)	28.19±14.35	<.001	64	2.29	24.30;31.60	1.727	.204	.079	0.522	.479	.025
	Pelvic tilt (°)	-25.50±10.11	<.001	64	3.00	-27.63; -22.64	0.067	.796	.002	4.671	.036	.100

Bike	Thoracic curv. (°)	-1.32±11.13	.169	64	0.19	-4.34;0.77	0.203	.659	.013	0.004	.952	.000
	Lumbar curv. (°)	28.24±13.19	<.001	64	2.71	25.38;31.65	2.544	.126	.113	0.412	.528	.020
	Pelvic tilt (°)	-6.13±10.79	<.001	64	0.78	-9.08; -3.82	4.821	.034	.103	0.511	.479	.012
Surfboard	Thoracic curv. (°)	3.69±7.39	<.001	64	0.35	1.74;5.44	2.672	.123	.151	5.866	.029	.281
	Lumbar curv. (°)	4.62±11.73	.002	64	0.48	2.16;8.73	0.736	.401	.035	3.511	.076	.149
	Pelvic tilt (°)	1.18±6.05	.166	64	0.14	-0.46;2.62	0.937	.339	.022	0.010	.920	.000
Air walker	Thoracic curv. (°)	2.23±7.62	.027	64	0.22	0.26;4.09	1.757	.205	.105	0.790	.388	.050
	Lumbar curv. (°)	0.62±8.65	.558	64	0.06	-1.53;2.82	0.984	.333	.047	0.001	.974	.000
	Pelvic tilt (°)	-1.10±6.06	.074	64	0.18	-3.02;0.14	0.827	.368	.019	0.751	.391	.018

OFE, outdoor fitness equipment; IP, Initial position; FP, Final position; curv, curvature; SBR, Single bonny rider.

ANCOVA analysis showed that sex was not an influential factor in the changes of sagittal spine disposition in the OFE ($F = 0.002$ - 2.672 ; $p = .123$ -. 966), with the exception of pelvic tilt in the Bike ($F = 4.821$; $p = .034$). When the covariable height was analyzed, it was found that this covariate significantly influenced pelvic tilt in the OFE performed in sitting (SBR and Row in both IP and FP) ($F = 4.671$ - 5.391 ; $p = .025$ -. 036), and thoracic curvature in the surfboard ($F = 5.866$; $p = .029$) (Table 2).

Table 3 shows bivariate correlations between spinal curvatures in the OFE and anthropometric variables. In almost cases anthropometric variables were correlated with the results obtained in the measurements of spinal curvatures. More specifically, body mass, BMI, waist-girth, hip girth, and biiliocrystal breadth were correlated with thoracic curvatures during the use of the OFE. Regarding lumbar curvatures, the anthropometric variables with significant correlations were height, hip girth, waist-hip ratio, and acromio-iliac index. However, pelvic tilt was the variables which showed a higher number of correlations with anthropometric variables. Correlations were found between pelvic tilt and height, waist-hip ratio, arm length, forearm length, upper limb length, biacromial breadth, and acromio-iliac index.

Table 3 Bivariate correlations between spinal curvatures in the outdoor fitness machines and anthropometric variables.

	Body Mass	Height	BMI	Sitting height	Cormic index	Waist girth	Hip girth	Waist-hip ratio	Arm length	Forearm length	Upper limb length	Biacromial breadth	Biiliocrystal breadth	Acromio-iliac index
Standing Thoracic curv.	$r = .307$ $p = .013$	$r = .111$ $p = .377$	$r = .316$ $p = .010$	$r = -.061$ $p = .628$	$r = -.367$ $p = .003$	$r = .442$ $p = .000$	$r = .254$ $p = .041$	$r = .277$ $p = .026$	$r = .268$ $p = .031$	$r = .207$ $p = .098$	$r = .249$ $p = .046$	$r = .148$ $p = .238$	$r = .340$ $p = .006$	$r = .237$ $p = .057$
Standing Lumbar curv.	$r = -.231$ $p = .064$	$r = -.213$ $p = .088$	$r = -.139$ $p = .270$	$r = -.172$ $p = .171$	$r = .097$ $p = .442$	$r = -.073$ $p = .561$	$r = -.251$ $p = .044$	$r = .154$ $p = .222$	$r = -.239$ $p = .055$	$r = -.172$ $p = .170$	$r = -.215$ $p = .085$	$r = .011$ $p = .931$	$r = -.171$ $p = .172$	$r = -.178$ $p = .157$
Standing Pelvic tilt	$r = .110$ $p = .381$	$r = .038$ $p = .762$	$r = .130$ $p = .301$	$r = .073$ $p = .562$	$r = .061$ $p = .63$	$r = -.057$ $p = .653$	$r = .257$ $p = .039$	$r = -.299$ $p = .015$	$r = .031$ $p = .804$	$r = -.035$ $p = .783$	$r = .000$ $p = .998$	$r = -.128$ $p = .31$	$r = .061$ $p = .629$	$r = .158$ $p = .209$
SBR IP Thoracic curv.	$r = .298$ $p = .016$	$r = .109$ $p = .388$	$r = .302$ $p = .015$	$r = .043$ $p = .735$	$r = -.149$ $p = .236$	$r = .425$ $p = .000$	$r = .247$ $p = .047$	$r = .26$ $p = .037$	$r = .256$ $p = .039$	$r = .168$ $p = .180$	$r = .223$ $p = .075$	$r = .104$ $p = .411$	$r = .269$ $p = .030$	$r = .200$ $p = .110$
SBR IP Lumbar curv.	$r = -.057$ $p = .652$	$r = .024$ $p = .849$	$r = -.094$ $p = .456$	$r = -.088$ $p = .485$	$r = -.239$ $p = .055$	$r = .026$ $p = .835$	$r = -.32$ $p = .009$	$r = .327$ $p = .008$	$r = .014$ $p = .915$	$r = -.012$ $p = .927$	$r = .002$ $p = .99$	$r = .188$ $p = .135$	$r = -.172$ $p = .171$	$r = -.322$ $p = .009$
SBR IP Pelvic tilt	$r = -.199$ $p = .113$	$r = -.402$ $p = .001$	$r = .089$ $p = .480$	$r = -.230$ $p = .065$	$r = .364$ $p = .003$	$r = -.194$ $p = .122$	$r = .232$ $p = .063$	$r = -.432$ $p = .000$	$r = -.412$ $p = .001$	$r = -.354$ $p = .004$	$r = -.399$ $p = .001$	$r = -.477$ $p = .000$	$r = -.003$ $p = .978$	$r = .352$ $p = .004$
SBR FP Thoracic curv.	$r = .170$ $p = .175$	$r = -.11$ $p = .382$	$r = .328$ $p = .008$	$r = -.147$ $p = .244$	$r = -.087$ $p = .490$	$r = .401$ $p = .001$	$r = .259$ $p = .037$	$r = .218$ $p = .081$	$r = .082$ $p = .518$	$r = .007$ $p = .956$	$r = .048$ $p = .706$	$r = -.057$ $p = .649$	$r = .134$ $p = .288$	$r = .18$ $p = .152$
SBR FP Lumbar curv.	$r = .024$ $p = .851$	$r = .274$ $p = .027$	$r = -.22$ $p = .078$	$r = .181$ $p = .15$	$r = -.194$ $p = .121$	$r = -.007$ $p = .955$	$r = -.368$ $p = .003$	$r = .331$ $p = .007$	$r = .226$ $p = .07$	$r = .247$ $p = .048$	$r = .245$ $p = .049$	$r = .311$ $p = .012$	$r = -.07$ $p = .581$	$r = -.305$ $p = .013$
SBR FP Pelvic tilt	$r = -.122$ $p = .335$	$r = -.328$ $p = .008$	$r = .135$ $p = .282$	$r = -.242$ $p = .052$	$r = .178$ $p = .156$	$r = -.09$ $p = .474$	$r = .236$ $p = .058$	$r = -.316$ $p = .01$	$r = -.329$ $p = .007$	$r = -.297$ $p = .016$	$r = -.326$ $p = .008$	$r = -.358$ $p = .003$	$r = .017$ $p = .892$	$r = .289$ $p = .02$
Row IP Thoracic curv.	$r = .209$ $p = .095$	$r = .055$ $p = .664$	$r = .234$ $p = .061$	$r = .039$ $p = .756$	$r = -.036$ $p = .778$	$r = .262$ $p = .035$	$r = .192$ $p = .124$	$r = .116$ $p = .358$	$r = .112$ $p = .373$	$r = .145$ $p = .249$	$r = .133$ $p = .29$	$r = .021$ $p = .869$	$r = .178$ $p = .155$	$r = .169$ $p = .179$
Row IP Lumbar curv.	$r = -.179$ $p = .153$	$r = .132$ $p = .296$	$r = -.369$ $p = .003$	$r = .078$ $p = .538$	$r = -.104$ $p = .41$	$r = -.157$ $p = .213$	$r = -.478$ $p = .000$	$r = .242$ $p = .053$	$r = .065$ $p = .608$	$r = .013$ $p = .919$	$r = .042$ $p = .742$	$r = .113$ $p = .37$	$r = -.178$ $p = .155$	$r = -.282$ $p = .023$
Row IP Pelvic tilt	$r = -.01$ $p = .937$	$r = -.421$ $p = .000$	$r = .364$ $p = .003$	$r = -.33$ $p = .007$	$r = .182$ $p = .148$	$r = .03$ $p = .811$	$r = .455$ $p = .000$	$r = -.367$ $p = .003$	$r = -.401$ $p = .001$	$r = -.357$ $p = .003$	$r = -.395$ $p = .001$	$r = -.379$ $p = .002$	$r = .076$ $p = .545$	$r = .366$ $p = .003$

Row FP	$r = .371$;	$r = -.005$;	$r = .492$;	$r = -.035$;	$r = -.072$;	$r = .478$;	$r = .485$;	$r = .104$;	$r = .062$;	$r = .081$;	$r = .074$;	$r = .004$;	$r = .353$;	$r = .359$;
Thoracic curv.	$p = .002$	$p = .969$	$p = .000$	$p = .782$	$p = .569$	$p = .000$	$p = .000$	$p = .408$	$p = .622$	$p = .519$	$p = .557$	$p = .977$	$p = .004$	$p = .003$
Row FP	$r = -.177$;	$r = .245$;	$r = -.451$;	$r = .178$;	$r = -.134$;	$r = -.136$;	$r = -.614$;	$r = .398$;	$r = .256$;	$r = .137$;	$r = .207$;	$r = .212$;	$r = -.287$;	$r = -.461$;
Lumbar curv.	$p = .159$	$p = .049$	$p = .000$	$p = .157$	$p = .286$	$p = .28$	$p = .000$	$p = .001$	$p = .039$	$p = .276$	$p = .098$	$p = .089$	$p = .02$	$p = .000$
Row FP Pelvic tilt	$r = -.012$;	$r = -.32$;	$r = .262$;	$r = -.245$;	$r = .156$;	$r = -.018$;	$r = .323$;	$r = -.309$;	$r = -.269$;	$r = -.209$;	$r = -.25$;	$r = -.337$;	$r = .031$;	$r = .293$;
	$p = .922$	$p = .009$	$p = .035$	$p = .049$	$p = .216$	$p = .884$	$p = .009$	$p = .012$	$p = .03$	$p = .094$	$p = .045$	$p = .006$	$p = .807$	$p = .018$
Bike Thoracic curv.	$r = .369$;	$r = .091$;	$r = .394$;	$r = .089$;	$r = -.012$;	$r = .431$;	$r = .326$;	$r = .195$;	$r = .206$;	$r = .146$;	$r = .186$;	$r = .143$;	$r = .223$;	$r = .106$;
	$p = .002$	$p = .466$	$p = .001$	$p = .477$	$p = .926$	$p = .000$	$p = .008$	$p = .116$	$p = .098$	$p = .241$	$p = .134$	$p = .252$	$p = .072$	$p = .397$
Bike Lumbar curv.	$r = -.011$;	$r = .115$;	$r = -.123$;	$r = .046$;	$r = -.15$;	$r = -.045$;	$r = -.284$;	$r = .209$;	$r = .057$;	$r = .074$;	$r = .068$;	$r = .165$;	$r = -.198$;	$r = -.323$;
	$p = .929$	$p = .359$	$p = .325$	$p = .716$	$p = .23$	$p = .722$	$p = .021$	$p = .092$	$p = .648$	$p = .553$	$p = .586$	$p = .187$	$p = .112$	$p = .008$
Bike Pelvic tilt	$r = -.191$;	$r = -.333$;	$r = .049$;	$r = -.251$;	$r = .178$;	$r = -.124$;	$r = .204$;	$r = -.328$;	$r = -.325$;	$r = -.347$;	$r = -.351$;	$r = -.38$;	$r = .102$;	$r = .385$;
	$p = .125$	$p = .006$	$p = .696$	$p = .042$	$p = .153$	$p = .319$	$p = .101$	$p = .007$	$p = .008$	$p = .004$	$p = .004$	$p = .002$	$p = .413$	$p = .001$
Surfboard Thoracic curv.	$r = .291$;	$r = .107$;	$r = .298$;	$r = .054$;	$r = -.121$;	$r = .406$;	$r = .311$;	$r = .185$;	$r = .206$;	$r = .117$;	$r = .17$;	$r = .038$;	$r = .289$;	$r = .269$;
	$p = .019$	$p = .396$	$p = .016$	$p = .667$	$p = .337$	$p = .001$	$p = .012$	$p = .139$	$p = .1$	$p = .352$	$p = .176$	$p = .762$	$p = .019$	$p = .03$
Surfboard Lumbar curv.	$r = .167$;	$r = .511$;	$r = -.228$;	$r = .4$;	$r = -.224$;	$r = .079$;	$r = -.276$;	$r = .351$;	$r = .441$;	$r = .447$;	$r = .462$;	$r = .356$;	$r = .005$;	$r = -.258$;
	$p = .184$	$p = .000$	$p = .068$	$p = .001$	$p = .073$	$p = .532$	$p = .026$	$p = .004$	$p = .000$	$p = .000$	$p = .000$	$p = .004$	$p = .971$	$p = .038$
Surfboard Pelvic tilt	$r = .176$;	$r = .012$;	$r = .228$;	$r = .028$;	$r = .037$;	$r = .027$;	$r = .31$;	$r = -.253$;	$r = -.025$;	$r = .02$;	$r = -.004$;	$r = -.044$;	$r = .197$;	$r = .234$;
	$p = .16$	$p = .927$	$p = .067$	$p = .825$	$p = .767$	$p = .829$	$p = .012$	$p = .042$	$p = .845$	$p = .877$	$p = .977$	$p = .725$	$p = .117$	$p = .061$
Air walker Thoracic curv.	$r = .311$;	$r = .1$;	$r = .336$;	$r = .025$;	$r = -.169$;	$r = .403$;	$r = .321$;	$r = .17$;	$r = .177$;	$r = .131$;	$r = .161$;	$r = .1$;	$r = .278$;	$r = .21$;
	$p = .012$	$p = .426$	$p = .006$	$p = .846$	$p = .179$	$p = .001$	$p = .009$	$p = .176$	$p = .157$	$p = .3$	$p = .2$	$p = .43$	$p = .025$	$p = .092$
Air walker Lumbar curv.	$r = -.115$;	$r = -.05$;	$r = -.109$;	$r = -.082$;	$r = -.065$;	$r = .053$;	$r = -.295$;	$r = .346$;	$r = -.03$;	$r = -.052$;	$r = -.042$;	$r = .056$;	$r = -.177$;	$r = -.217$;
	$p = .362$	$p = .693$	$p = .387$	$p = .518$	$p = .605$	$p = .675$	$p = .017$	$p = .005$	$p = .811$	$p = .679$	$p = .737$	$p = .655$	$p = .158$	$p = .083$
Air walker Pelvic tilt	$r = .077$;	$r = -.045$;	$r = .139$;	$r = -.031$;	$r = .026$;	$r = -.031$;	$r = .207$;	$r = -.232$;	$r = -.025$;	$r = -.021$;	$r = -.024$;	$r = -.089$;	$r = .102$;	$r = .169$;
	$p = .544$	$p = .72$	$p = .269$	$p = .809$	$p = .835$	$p = .808$	$p = .098$	$p = .063$	$p = .843$	$p = .87$	$p = .851$	$p = .481$	$p = .417$	$p = .177$

SBR, Single bonny rider; curv, curvature; FP, Final Position; IP, Initial Position.

According to the multiple linear regression analysis (Table 4), the variables height and the cormic index explained most of the spinal changes during the use of the different OFE. More specifically, the subjects with a higher cormic index were more at risk of increasing their thoracic kyphosis in the SBR, row, bike, surfboard and air walker. In turn, those subjects with a higher cormic index showed a higher risk of decreasing lumbar lordosis towards kyphotic positions in the IP of the SBR, while those subjects with a higher height had a higher risk of decreasing lumbar lordosis towards kyphotic positions in the FP of the SBR and row, bike and surfboard machines. Likewise, taller subjects had a greater risk of decreasing pelvic anteversion towards pelvic retroversion positions in SBR, row and bike.

Table 4 Stepwise multiple linear regression analysis of the relationship of differentiation of spinal curvatures in the outdoor fitness machines with anthropometric variables.

	Difference OFE-Standing	R ²	p Value	Included independent variables	Standardized Coefficient (β)
SBR	IP Thoracic curv. (°)	.060	.049	Cormic index	0.245
	IP Lumbar curv. (°)	.080	.023	Cormic index	0.283
	IP Pelvic tilt (°)	.160	.001	Height	-0.400
	FP Thoracic curv. (°)	.111	.007	Cormic index	0.332
	FP Lumbar curv. (°)	.172	.001	Height	0.415
	FP Pelvic tilt (°)	.163	.001	Height	-3.486
Row	IP Thoracic curv. (°)	.175	.001	Cormic index	0.419
	IP Lumbar curv. (°)	.089	.016	Height	0.298
	IP Pelvic tilt (°)	.197	.000	Height	-0.444
	FP Lumbar curv. (°)	.152	.001	Height	0.390
	FP Pelvic tilt (°)	.114	.006	Height	-0.338
Bike	Thoracic curv. (°)	.158	.001	Cormic index	0.398
	Lumbar curv. (°)	.100	.010	Height	0.316
	Pelvic tilt (°)	.137	.002	Height	-0.370
Surfboard	Thoracic curv. (°)	.127	.004	Cormic index	0.357
	Lumbar curv. (°)	.368	.000	Height	0.606
Airwalker	Thoracic curv. (°)	.088	.016	Cormic index	0.297

OFE: outdoor fitness equipment; SBR: Single bonny rider; curv: curvature; FP: Final Position; IP: Initial Position.

5.10. DISCUSSION

Most older people suffer from changes in the sagittal spine disposition in different positions, due to a loss of strength, muscle shortening, reduced mobility, and stiffness of passive structures such as ligaments and discs (Norasteh et al., 2019). Therefore, it is necessary to evaluate the spine disposition not only in standing, but also in different positions in daily life and sports practice in order to analyze the adaptations that occur during these activities (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2009). However, most previous studies have only analyzed middle-aged and older adults in a standing position (Asai et al., 2017; Elsayed et al., 2018; Kasukawa et al., 2017; Keller et al., 2005; Ohyama et al., 2019). For this reason, in the present study, we analyzed the sagittal disposition of the spine of middle-aged and older adults in standing position, but also in the different OFE that are most frequently installed in the bio-healthy parks.

The main finding of the present investigation was that in general, there were significant differences in the sagittal spine disposition and pelvic tilt during the execution of the exercises with the machines, as compared to the relaxed standing position in middle-age and older adults.

In the OFE that were performed in the two-legged position, as was the case with the surfboard and air walker, an increase in thoracic kyphosis was found when using these OFE, without changes in lumbar curvature or pelvic tilt in general. Coinciding with these results, previous studies have shown that when a frontal grip has to be performed, with internal rotation and/or shoulder adduction, it is common to find greater thoracic kyphosis than in a relaxed standing position (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2010; Muyor, 2015), especially in the event that this provision is accompanied by a maintained grip (Imagama et al., 2014; Kordi et al., 2019). This is especially relevant considering that the presence of hyperkyphotic thoracic curvatures during the execution of fitness exercises could lead to a lower involvement of the musculature that is mainly involved in the exercise. This could result in a greater shortening of the flexor and internal rotator muscles in the shoulder, a decrease in joint mobility, and changes in biomechanics and in the position of the center of gravity, among other factors (Imagama et al., 2014; Kordi et al., 2019), which could increase the risk of falls, back pain and loss of function (Norasteh et al., 2019).

In the sedentary machines, the grip was in a more neutral position and with less activation of the upper limb musculature, which could influence the degree of tension of the stabilizing musculature in the scapulo-humeral joint and the thoracic area to adopt more neutral positions (Imagama et al., 2014; Kordi et al., 2019). However, in sedentary exercises performed in OFE, there was a decrease in lumbar lordosis and pelvic anteversion. Previous studies found the same tendency toward decreased lumbar lordosis and pelvic anteversion when analyzing the disposition of the spine and pelvic tilt during sedentary exercise positions in older individuals (Norasteh et al., 2019). This disposition was also found during other sports actions that required executing force from a sitting position (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2010). More specifically, previous studies found that in the case of starting from a sedentary, sitting position, the technical gesture requires performing a pulling movement with the upper limbs fully extended, the trunk inclined and the knees semi-extended, as is the case of row and SBR, there was an adaptation in the pelvic tilt and lumbar disposition (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2012). This is especially relevant if we take into account that people who adopt a kyphotic position in the lumbar area in situations of load mobilization have a higher probability of suffering pathologies such as herniated and protruded discs, low back pain, spondylolysis and spondylolisthesis, among others (McGill et al., 2014). Therefore, it would be advisable to modify the design of this type of machines to allow for a normal disposition of the lumbar spine during the execution of guided exercises (McGill et al., 2014). Despite these promising results, questions still remain.

Another of the objectives of the present investigation was to analyze whether anthropometric variables could condition the sagittal disposition of the spine and pelvic tilt during the use of the OFE, finding that anthropometric variables significantly influenced the adaptations in the sagittal spine disposition and pelvic tilt. Previous studies have already pointed out that anthropometric variables could condition the sagittal spine disposition when performing actions involving the application of force (Abelleira-Lamela et al., 2020; Elsayed et al., 2018). However, until now, no studies had been conducted which analyzed this issue in OFE.

More specifically, it was found that in general, the users with a greater height and/or with a higher cormic index, whose sitting height was proportionally larger than the sitting height, were more likely to be taller (Esparza-Ros et al., 2019), have

a greater probability of presenting kyphotic thoracic curves, as well as kyphotic positions of the lumbar area, together with a greater probability of showing pelvic retroversion in the machines that were executed in a sedentary position. In addition, in the ANCOVA analysis, height was found to be a covariate that significantly influenced pelvic tilt in the OFE performed in sitting in the IP and FP, as well as thoracic curvature in the surfboard. The differences in pelvic tilt may have been due to the participants were sitting on the OFE and the taller subject will be able to perform the grips in a more upright position, thus requiring less pelvic tilt in terms of grip as it has been found using other kinds of sport equipment (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2012; Muyor, 2015). Regarding thoracic curvature, it was found that height influenced the surfboard, but not the air walker, even though both were in standing position. This could be due to the grip, since the air walker has a higher frontal grip, while the surfboard has a lateral grip at hip height, so that a greater trunk flexion is required to maintain the grip. Previous studies have already found that the number of subjects with thoracic hyperkyphosis is higher in this type of position when there is no proper postural hygiene (Farrag et al., 2015; Mawston et al., 2007).

In contrast, the anthropometric parameters related to the transverse dimension had no influence on the sagittal disposition of the spine in middle-aged or older adults. This could be a consequence of the fact that one of the problems presented by the OFE in relation to ergonomics is that it cannot be adjusted according to the anthropometric characteristics of the users (Chow & Wu, 2019), in contrast to what happens in the classic fitness room equipment (Chow & Wu, 2019). Thus, it is likely that in those subjects who are taller or whose trunk is longer, the grip remains low, having to perform a thoracic hyperkyphosis in order to hold themselves. The disposition of the thoracic spine could in turn condition the disposition of the lumbar curvature and pelvic tilt (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015), which would explain the presence of inversions in the lumbar area and pelvic retroversion positions accompanying thoracic hyperkyphosis dispositions, especially when the execution has to be carried out from a sedentary position (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015). This tendency towards flattening of the lumbar curvature and pelvic tilt observed in the sagittal spine disposition during the use of OFE would be contrary to the ideal position. In this regard, the curved disposition of the spine in the

sagittal plane is essential, as the strength of an element is equal to the number of curvatures squared plus one (Kapandji., 1981), the almost aligned disposition of the lumbar spine and the pelvic tilt would detract from the strength of the spine. In addition, the spine is more resistant to axial compression and more stable with the presence of these curves than without them (Panjabi et al., 1985), allowing for an efficient absorption of the loads applied to the spine (Adams & Dolan., 1996; Kapandji., 1981) and increasing the efficiency of the paravertebral musculature (Dickson., 2004). Therefore, the misalignments of the thoracic and lumbar curvatures, together with the external load caused by the performance of the exercises, could increase intervertebral stress and spinal loads (Keller et al., 2005). For all these reasons, it would be necessary to redesign the OFE, evolving towards models that would allow adjusting the distances between footrests, seats and grips according to the size and seated size of middle-aged and older adults.

Another of the objectives of the present investigation was to analyze whether the sex covariate influenced the changes that occurred in the sagittal spine disposition on the OFE. A much debated question is whether sex influence sagittal spine disposition. Specifically, some papers have found that women show a greater probability of presenting lumbar hyperlordosis than men in adulthood (Bailey et al., 2016), while others have showed similarity in the sagittal spine disposition between men and women (Endo et al., 2012; Janssen, 2010; Yeh et al., 2018). In the present investigation it was found that sex did not influence the sagittal spine disposition and pelvic tilt adopted in the OFE. This could be due to the fact that other factors are affecting the adaptations that occur in the sagittal arrangement of the spine when using this type of fitness equipment.

As a strength of the research, this is the first study that analyzes the disposition of the spine in the OFE, and the sample investigated was large. Regarding the limitations of the present study, although the sample of the present study was large as compared to other, similar studies, the sample of men was somewhat reduced, perhaps because men do not find these types of machines useful and, therefore, this is another reason to investigate the safety and effectiveness of the OFE. In addition, since we only had one model of each machine and not different prototypes of each one, we could not analyze the influence of changes in the disposition of the machines on the sagittal spine disposition. Thus, this could be a future line of research with which to analyze whether the

modification of the OFE allows for a safer and healthier sagittal spine disposition and pelvic tilt of its users. On the other hand, it will be possible to contrast the results of the present investigation in professional equipment that does allow an adaptation of the equipment according to the anthropometric characteristics of the user, such as fitness equipment as well as looking for new ways of using the machines to make them as versatile as possible. Another limitation of the present investigation was that the evolution of low back pain or other spinal pathologies during the use of OFE was not analyzed. This should be addressed in future research.

5.11. CONCLUSIONS

Middle-aged and older adults show spinal misalignments when using the OFE with respect to the standing position, showing a significant decrease in the thoracic kyphosis in the IP of SBR and ROW, and a significant increase in the surfboard and air walker, and in the FP of Row; a significant decrease in the lumbar lordosis in all OFE with the exception of the air walker; and a significant decrease in the pelvic anteversion in all the OFE in sitting (SBR, Bike and Row). Height and the cormic index conditioned these adaptations, showing that middle-aged and older-adults with higher height and cormic index had a higher probability of showing increased thoracic kyphosis, lumbar kyphosis, and pelvic retroversion. This are the reason for the recommendation of the manufacturing of safer outdoor fitness equipment that allows users to adjust them to their anthropometric needs.

**ESTUDIO 3: IMPROVING SPINAL
ALIGNMENT THROUGH INNOVATIVE
RESISTANCE TRAINING WITH
OUTDOOR FITNESS EQUIPMENT IN
MIDDLE-AGED AND OLDER ADULTS:
A RANDOMIZED CONTROLLED TRIAL**

Vc - ESTUDIO 3 - Improving Spinal Alignment Through Innovative Resistance Training With Outdoor Fitness Equipment in Middle-Aged and Older Adults: A Randomized Controlled Trial

5.12. ABSTRACT

The main objective of this study was to analyze the effect of a resistance training program using outdoor fitness equipment (OFE) on sagittal spine disposition and pelvic tilt in middle-aged and older adults. One hundred and twenty-eight middle-aged and older adults were randomly assigned to the training (TG) or control group (CG). The TG trained for 8 weeks, with 2 weekly sessions of one hour of resistance circuit training with OFE. Before and after the intervention, the sagittal spine disposition and pelvic tilt in the relaxed standing and sitting positions were analyzed. The results showed that the TG obtained a significant reduction ($p < .001$) in all the curvatures of the sagittal spine disposition and pelvic tilt in the standing position after the intervention, in contrast to the CG, which only showed a significant reduction in pelvic tilt ($p = .005$). Regarding the sitting position, only the TG presented a significant decrease in lumbar lordosis ($p < .001$). In conclusion, resistance training with OFE may be useful in improving sagittal spine disposition in middle-aged and older adults. Given the availability of free OFE in parks, the present research provides elders with an accessible and effective training program to curb the effects of ageing on the sagittal spine disposition.

5.13. INTRODUCTION

Current scientific evidence describes an increase in thoracic curvature while standing as a person ages (Ailon et al., 2015; Ohyama et al., 2019; Urrutia et al., 2022), without a clear trend for lumbar curvature in the standing position in this population. While some studies find that it often flattens during this stage, other studies show that it increases (Arshad et al., 2019; Grabara, 2013; Ostrowska et al., 2003). Not surprisingly, previous studies have found that 20–40% of older adults have thoracic hyperkyphosis in the standing position (Kado et al., 2004, 2007; Pai et

al., 2021), with the incidence of older adults showing hyperlordosis in the standing position also being high (Pai et al., 2021).

This increase has been linked to a poorer health status, characterized by respiratory problems, greater loss of physical function, lack of mobility, risk of falling, back pain in general, and low back pain in particular, and even mortality (Ailon et al., 2015; Arja et al., 2003; Imagama et al., 2013; Jenkins et al., 2021; Kasukawa et al., 2017; Roghani et al., 2024; Wong et al., 2017). In addition, pathologies such as spondylolysis, spondylolisthesis or degenerative changes in the intervertebral discs have also been linked to spine misalignments (Ames et al., 2016; Been & Kalichman, 2014).

One of the factors that could be associated with the increase in sagittal curvatures of the spine beyond the normal range with age is the loss of physical conditioning (Ailon et al., 2015). A relationship has also been found between changes occurring in the sagittal spine disposition and loss of strength (Hongo et al., 2012; Imagama et al., 2013; Liang et al., 2016; Mika et al., 2005; Rissanen et al., 1995). Specifically, it has been found that a deficit in the strength of the extensor muscles of the trunk is related to an increase in thoracic hyperkyphosis and hyperlordosis or rectification of the lumbar area, as well as an alteration of the lumbo-pelvic dynamics (Ailon et al., 2015; Hongo et al., 2012; Kasukawa et al., 2017; Mika et al., 2005). In addition, strength deficits in the trunk muscles, with the subsequent changes in the sagittal spine disposition, increase the risk of suffering from some pathologies such as herniated discs (Arja et al., 2003).

As a result of the aforementioned factors, various studies have suggested the implementation of comprehensive exercise training programs, with a specific emphasis on resistance training to enhance sagittal spinal disposition (Glassman et al., 2006; Kernc et al., 2018; Ponzano et al., 2021). Thus, most of these studies have implemented multicomponent programs, usually including stretching or postural hygiene exercises together with resistance work as well (González-Gálvez et al., 2019; Jenkins et al., 2021). Therefore, the effect of exclusive resistance training on the sagittal spine disposition is lightly studied but promising (Bergström et al., 2011; Harding et al., 2021; Jenkins et al., 2021; Watson et al., 2019). In addition, very few of these studies have focused on the adult/older population (Bergström et al., 2011; Harding et al., 2021; Katzman et al., 2017; Watson et al., 2019). Likewise, reviews on the effect of strength training on spinal disposition have shown that a

full body circuit based on different types of overload training, such as using gym equipment, dumbbells, or weighted backpacks, can improve thoracic alignment in elders as long as sufficient overload and training volume is achieved (Bansal et al., 2014). This could be due to the fact that in most of these interventions, the trunk musculature is not worked on exclusively, but most of the exercises focus on the upper and lower limb musculature, with the trunk musculature being involved as a synergist, so that the generation of sufficient overload seems to be a limiting factor in the effects of these interventions on the sagittal spine disposition (Bansal et al., 2014). However, these interventions have been focused on different methodologies used for strength training, such as gym equipment, self-loading exercises, dumbbells, weighted backpacks or elastic bands, with very different results reported between them, which could be due to the differences in the training programs proposed, the training volume, the overloading of the different training systems used, or the characteristics of the population included (Bansal et al., 2014).

In this line, despite the many investigations carried out with different types of equipment, including traditional machines (Harding et al., 2021; Hojjati & Sheikhpour, 2023), it should be noted that none of these previous studies have used outdoor fitness equipment (OFE) for resistance training. In general, OFE machines are specially designed for adults and older adults, with a friendly design and a simple operation (Chow et al., 2017; Chow & Wu, 2019). Many public entities worldwide have used them with the aim of achieving a healthy aging of the population by making access to OFE simple and free of charge (Abelleira-Lamela et al., 2021; Fernández-Rodríguez et al., 2020). The location of these machines in public spaces and their free-of-charge use, provide greater availability and accessibility as compared to traditional machines. In addition, although they are more oriented towards the older population, they are commonly used by people of all age groups (Chow et al., 2017), so that a larger population group in multiple countries (Fernández-Rodríguez et al., 2020) could benefit from their use over traditional gym machines. In fact, this type of installation has been booming in recent years.

OFE is a very interesting option for guided resistance training with exercise equipment. Theoretically, training with OFE should influence the sagittal spine disposition by strengthening the adjoining and stabilizing trunk and back musculature such as abdominal obliques, rectus abdominis, multifidus, transverse

abdominal, quadratus lumborum, erector spinae or dorsal, among others (Abelleira-Lamela et al., 2024a; Hrysomallis & Goodman, 2001; Karimizadeh Ardakani et al., 2022). These muscles act as synergists when pulling or pushing with the upper limb, or movements involving hip flexions or extensions, movements for which many OFE are designed (Marcos-Pardo et al., 2024). In fact, previous studies have shown that training on OFE-like machines such as guided gym machines can improve sagittal spine posture as a result of the activation generated by these machines in synergist muscles that act as stabilizing musculature of the trunk and back (Bansal et al., 2014; González-Gálvez et al., 2019; Lorenzetti et al., 2017; Schubert et al., 2016; Sung et al., 2015). However, although OFE machines are training devices with certain similarities to traditional gym machines, unlike traditional gym machines in the OFE the user's own weight is used as the load by means of a system of levers (Abelleira-Lamela et al., 2024a, 2024b). Previous studies have shown that their use can improve body composition and functionality, and increase strength in arms and legs (Marcos-Pardo et al., 2024). Furthermore, OFEs have been designed without regard to safety or ergonomic principles (Abelleira-Lamela et al., 2021). This therefore raises the question of whether the OFE machines can achieve long-term beneficial effects on the sagittal disposition of the spine despite their design, or provide sufficient stimulus, as has been found with other strength training systems (Bergström et al., 2011). It is therefore essential to know the effects of training with this type of equipment on the sagittal spine disposition.

Therefore, the aim of the present study was to analyze the effect of a resistance training program using OFE on the sagittal spine disposition and pelvic tilt of middle-aged and older adults. The hypothesis of the present study is that resistance training with OFE will improve the sagittal spine disposition and pelvic tilt of middle-aged and older adults.

5.14. MATERIALS AND METHODS

5.14.1. Study design

The present study is an 8-week randomized controlled trial. The trial design was registered with ClinicalTrial.gov (identifier: NCT04958499) and followed the

Consolidated Standards of Reporting Trials (CONSORT) guidelines and the Template for Intervention Description and Replication (TIDieR) checklist. The research was conducted in accordance with the Declaration of Helsinki. Approval was obtained from the Ethics Committee of the Universidad Católica San Antonio de Murcia (Ethical Application Ref: CE111908) before the start of the project. All participants were informed of the study evidence as well as any potential risks and possible adverse effects, and voluntarily signed an informed consent form prior to the measurements and intervention, and also provided their consent to have their photographs taken for subsequent publications.

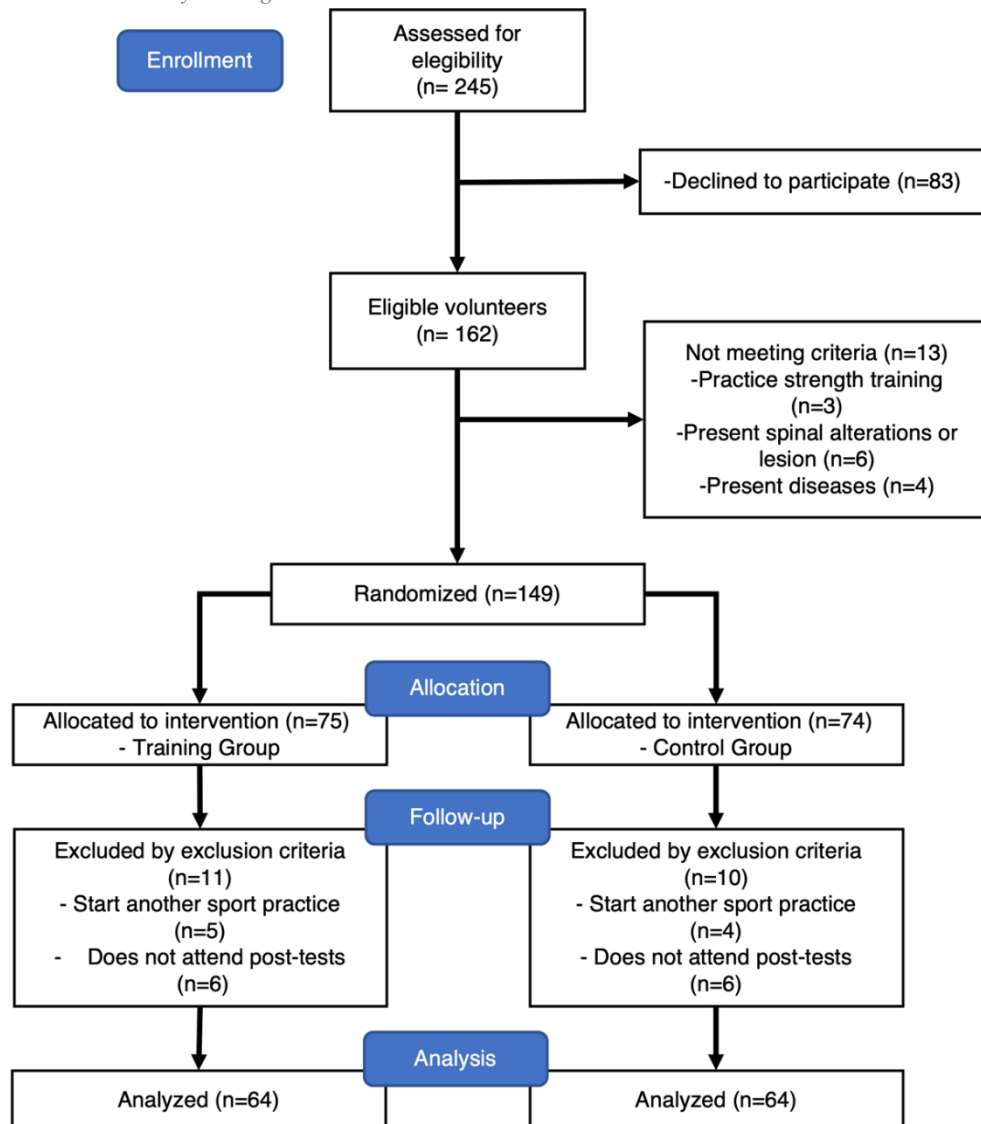
5.14.2. Participants

The minimum sample size necessary for the study's development was calculated using Rstudio 3.15.0 software (Rstudio Inc., USA), and followed the methodology employed in previous studies (Bhalerao & Kadam, 2010), which also provided the standard deviation (SD) from prior studies that measured thoracic kyphosis in standing position for a sample of older adults ($SD = 8.5^\circ$) (Watson et al., 2019). This standard deviation was chosen after selecting a study that showed a sample similar to the present one. In addition, to be conservative, a standard deviation that was slightly higher than the norm was used to ensure the sample and power size. With an estimated error (d) of 2.12, a confidence interval of 95%, a significance power of 95% ($1-\beta = 0.95$), and a significance level of .05, the required sample size was determined to be 62 volunteers. To be cautious and to avoid a high sample loss after the end of the intervention, a dropout rate of 20% was assumed, based on previous studies (Nayasista et al., 2022; Watson et al., 2019) that had similar characteristics to the present one. Thus, a minimum of 74 participants per group was required.

The participants were recruited on a voluntary basis through informative conferences and advertising in different senior centers in the Region of Murcia (Spain). The inclusion criteria were: a) being over 50 years of age; and b) not performing resistance training or physical exercise regularly. The exclusion criteria were: a) suffering from any spinal disorder or injury that prevented the performance of the measurements and/or training; b) having undergone surgery that prevents/poses a risk towards performing any of the tests and/or training; c)

presenting any neurological, cardiovascular, musculoskeletal or metabolic alterations at the time of the measurement/training; d) missing the post-test evaluations; and e) starting to perform physical exercise systematically during the time of the study. The final sample consisted of 128 middle-aged and older adults, 46 men (mean age: 60.50 ± 5.96 years) and 82 women (mean age: 58.04 ± 7.62). They were randomized into the training group (TG) ($n = 64$; 24 males and 40 females; mean age: 60.02 ± 7.25 years) and control group (CG) ($n = 64$; 22 males and 42 females; mean age: 57.83 ± 6.92 years). The CONSORT flow diagram is shown in Fig. 1.

Figure 1. CONSORT flow diagram.



5.14.3. Randomization and blinding

After the recruitment and selection of the sample, the participants were assigned to the different groups. The group assignment was blinded and was carried out using a computer-generated random number table by a researcher in the presence of other researchers unrelated to the present investigation. Two groups were established according to the thoracic curve, as in previous research (González-Gálvez et al., 2021), and then a random sequence was generated to create the groups by stratified randomization. The researchers who performed the spinal measurements were not present at the training sessions. The two researchers involved in data collection were also cross-blinded in the measurements, where one carried out the measurement using the device, while the other was only responsible for verifying the correct recording of the data. During randomization, an attempt was made to keep married couples in the same group, as well as social groups, to increase adherence, following the methodology from previous studies (Kemmler et al., 2020).

5.14.4. Measurements

The measurements were performed in a sports science laboratory at a standardized temperature of 24 °C between 10:00 and 14:00 h. The participants were requested to not stretch or warm up prior to the tests. During the measurements, the participants remained barefoot on an insulating mat.

First, the basic variables of body mass and height were measured according to the protocol from the International Society for the Advancement of Anthropometry (ISAK) (Esparza-Ros et al., 2019). All the measurements were performed by an ISAK Level 1 accredited anthropometrist. A Tanita BC-545N scale (Tanita, Arlington Heights, Illinois, USA) was used to measure body mass. A HR001 portable stadiometer (Tanita, Arlington Heights, Illinois, USA) was used to measure height.

Subsequently, the sagittal spine disposition and pelvic tilt were measured using the Spinal Mouse® system (Idiag, Fehraltorf, Switzerland). This device allows the angular measurement of the different spinal curvatures in a non-invasive way by means of a wireless device connected to a computer. This tool has shown high intra- and inter observer validity and reliability, with the following

correlation coefficients, respectively (0.61–0.96; 0.70–0.93) (Kellis et al., 2008). An assessment of the sagittal spine disposition and pelvic tilt in relaxed standing and sitting positions was performed, following the protocol from previous studies (López-Miñarro et al., 2012; Muyor et al., 2016). In the standing position, the volunteers stood with their shoulders relaxed, looking forward, with their arms along their trunk, and their feet hip-width apart. For the sitting position, the volunteers were placed in a relaxed sitting position on a box, without thoracic or lumbar support, with their hands resting on their thighs, and with their knees bent at 90°. A positive value implied a pelvic kyphosis/anteversion, while a negative value implied a pelvic lordosis/retroversion. All the assessments were performed by the same measurer, who had previous experience in performing similar interventions.

5.14.5. Intervention

The intervention program was carried out in an OFE circuit, consisting of eight OFE machines (Bonny rider, Air Walker, Surfboard, Row, Parallel bars, Gemini, Flyers wheels and Swing) from the company Entorno Urbano S.L.U (Murcia, Spain), which was located in a private and reserved area for study within the Universidad Católica San Antonio de Murcia, Murcia, Spain.

The TG participants performed a training program using the OFE for 8 weeks, with 2 weekly sessions lasting one hour per session on non-consecutive days. CG participants did not perform any training and were asked to maintain their usual lifestyle. The researchers in charge of conducting the training sessions recorded attendance using Excel software. Average program attendance was 92.75% (min: 78.57%, max: 100%).

The training sessions consisted of resistance circuit training with 11 self-loaded exercises (Table 1) to be performed on the eight OFE machines, following the example from previous research (Marcos-Pardo, Espeso-García, Vaquero-Cristóbal, et al., 2023). In the selection of exercises, it was taken into account that there were exercises that involved the dorsal musculature, hip extensors, scapular approximators or abdominal muscles, among others. The execution speed was set by a metronome (Clemons, 2019). The training program was designed and supervised by Sports Science graduates with Master's degrees in Strength and

Conditioning Training, Healthy Aging, and Physical Activity and Health. The training protocol performed is described in Table 2. The training load was regulated by time under tension. A digital metronome was used to set the execution rhythm of the concentric and eccentric phases in each OFE (Vargas-Molina et al., 2020).

Table 1. Exercises to be performed in the outdoor fitness equipment circuit.

Exercise	Method of use	Representation
Bonny rider	Using a supine grip, pull the handle with both hands by flexing the elbow and extending the shoulder.	
Shoulder press	On the Gemini machine, taking the grips at a low height, push the handle by elbow extension and shoulder flexion.	
Air Walker	Holding and on both platforms, perform hip flexion-extensions keeping the trunk perpendicular. Hold briefly and isometrically at the end of the range of motion.	
Tricep dips	On the parallel bars, holding with both hands and starting with the elbow flexed, extend it by overcoming the load of the user's own weight. Adaptation: Triceps push-ups with prone grip sideways to the machine.	
Shoulder wheel	On the Flyers Wheels machine, with elbows fully extended and grasping the grips, perform circumduction through shoulder mobility.	

Chest press	On the Gemini machine, holding the grips at a middle height, push the handle by elbow extension and shoulder flexion.	
Rotator wheel	Cuff On the <i>Flyers wheels</i> machine on the side, support the elbow and take the grip. Perform internal and external rotation	
Calf raise	On the Swing machine, with the knee extended, rest the metatarsal on the lower edge of the platform. Flex and extend the ankle.	
Surfboard	Standing on the platform and holding on to the handle, perform from the waist the pendulum movement in the frontal plane. Hold briefly and isometrically at the end of the range of motion.	
Leg press	On the <i>Swing</i> machine, sitting with feet on the platforms, push through knee extension to overcome the load.	
Row	Sitting on the seat, and with the feet in position, pull on the grip by flexing the elbow and externally rotating the shoulder, keeping the trunk perpendicular to the ground.	

Table 2. Training planning.

Week	Sets	T of work / exe (s)	Reps Exe	Concentric/ec centric (repetition/s)	T rest/exe (s)	T rest/set (min)	T session (min)	Total Reps/ session
1	1	30	15	1/1	45	-	13.75	165
2	2	30	15	1/1	30	2	27	330
3	3	30	15	1/1	30	4	43	495
4	3	30	15	1/1	30	4	43	495
5	3	45	15	1/2	30	4	51.25	495
6	3	45	15	1/2	30	4	51.25	495
7	3	45	11	2/2	30	4	51.25	371
8	3	45	11	2/2	30	4	51.25	371

Exe exercise, Reps repetitions, T time.

5.14.6. Statistical analysis

After analyzing the normality of the variables using the Kolmogorov–Smirnov test, as well as kurtosis, skewness, and variance, Mauchly’s W-test was used to evaluate the sphericity of the data. Two-way ANOVAs with one-way repeated measures were carried out to analyze inter- and intra-group differences. Partial eta squared (η^2) was used to calculate the effect size and was defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: ≥ 1.2 ; or very large: $ES \geq 2.0$, with an error of $p < .05$ (Hopkins et al., 2009). A value of $p < .05$ was set to determine statistical significance.

The statistical analysis was performed with the SPSS statistical package (v. 25.0; SPSS Inc., IL).

5.15. RESULTS

Regarding the intergroup baseline differences, Table 3 shows homogeneity in the variables age, gender, marital status, level of education, occupation, who they live with, and number of falls in the last year ($p > .05$).

Table 3. Comparison of demographic characteristics in training group and control group.

	TG (X±SD or n(%))	CG (X±SD or n(%))	χ^2/t	<i>p</i>
Age (years)	60.02 ± 7.25	57.83 ± 6.92	0.66	.511
Gender	Female: 40 (62.5%)	Female: 42 (65.6%)	0.66	.416
	Male: 24 (37.5%)	Male: 22 (33.4%)		
Marital status	Single: 5 (7.8%)	Single: 3 (4.7%)	5.48	.242
	Married: 43 (67.2%)	Married: 51 (80.0%)		
	Divorced: 11 (17.2%)	Divorced: 3 (4.7%)		
	Widower: 5 (7.8%)	Widower: 7 (10.9%)		
Level of education	Primary: 13 (20.3%)	Primary: 16 (25.0%)	3.23	.358
	Secondary: 16 (25.0%)	Secondary: 18 (28.1%)		
	Baccalaureate: 12 (18.8%)	Baccalaureate: 12 (18.8%)		
	University: 23 (35.9%)	University: 19 (29.7%)		
Occupation	Full-time employee: 21 (32.8%)	Full-time employee: 20 (31.3%)	4.34	.502
	Part-time employee: 7 (10.9%)	Part-time employee: 9 (14.1%)		
	Self-employed: 6 (9.4%)	Self-employed: 9 (14.1%)		
	Unemployed: 7 (10.9%)	Unemployed: 8 (12.5%)		
Who they live with	Retired: 23 (35.9%)	Retired: 18 (28.1%)	1.89	.594
	Partner: 46 (71.9%)	Partner: 49 (76.6%)		
	Family: 8 (12.5%)	Family: 6 (9.4%)		
	Alone: 10 (15.6%)	Alone: 9 (14.1%)		
Falls in the last year (n)	0.29 ± 0.68	0.30 ± 0.47	-0.09	.931

TG: training group; CG: control group

Table 4 shows the pre-post intervention differences in the sagittal spine disposition and pelvic tilt in each of the groups. In the standing position, there was a significant reduction in thoracic kyphosis, lumbar lordosis and pelvic anteversion of the TG after the intervention ($p < .001$). In contrast, the CG showed no significant differences in thoracic or lumbar curvatures ($p = .863$; $p = .053$), although a significant decrease in pelvic tilt ($p = .005$) was observed. There were no significant changes in either the TG or CG in the sitting position results, except for a decrease in lumbar lordosis in the TG ($p < .001$). These results are shown in Fig. 2.

Table 5 shows the differences between the TG and CG in the pre-post change. The TG showed a significantly greater reduction than the CG in thoracic curvature, lumbar curvature, and pelvic tilt in the standing position ($p = .024$ – $< .001$). In the sitting position, a greater reduction in thoracic and lumbar curvature was found in the TG than in the CG ($p = .023$ – $.002$). There was no difference in the change that occurred in the pelvic tilt when sitting between groups ($p = .607$).

Table 6 shows the differences in pre- and post-test changes between standing and sitting positions. Significantly greater reductions in thoracic and lumbar curvatures and pelvic tilt were observed in the standing position than when sitting ($p < .001$).

Figure 2. Sagittal spine disposition and pelvic tilt in standing and sitting positions in both measurements for the training group and the control group.

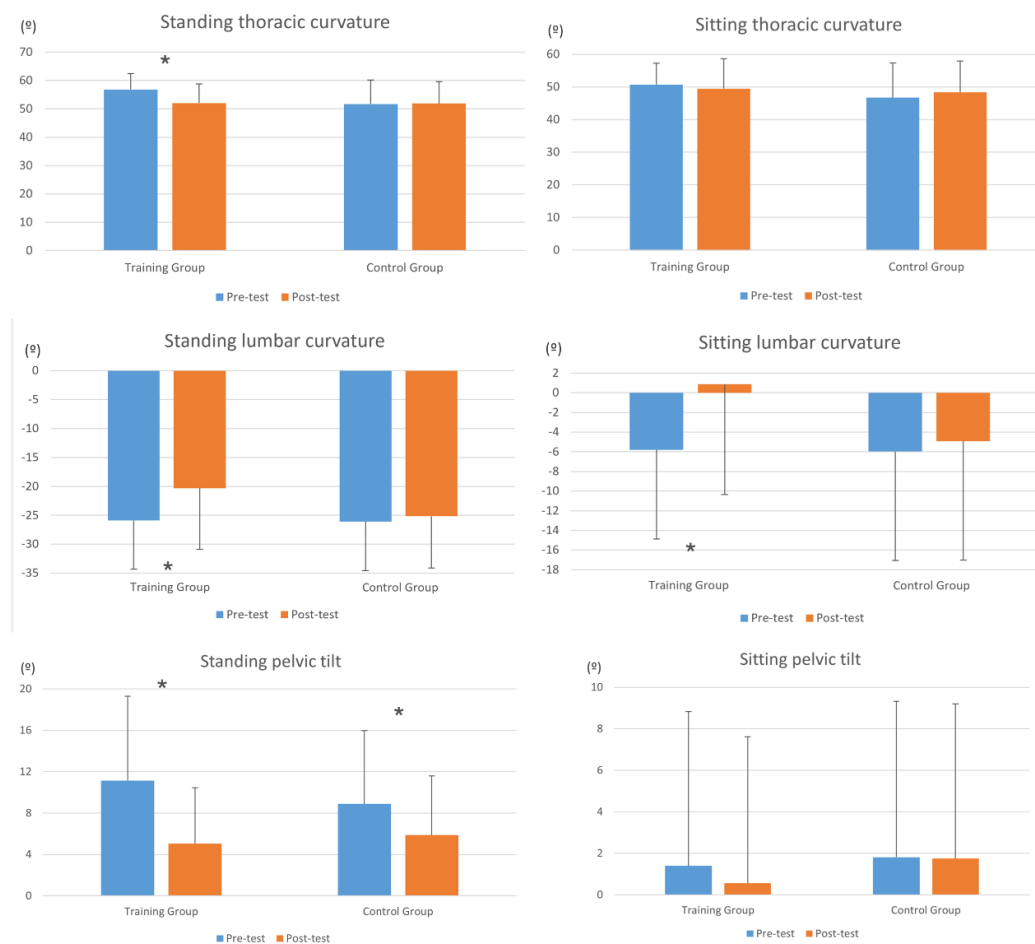


Figure caption: * indicates that the pre-post differences are $p < 0.05$.

Table 4. Intra-group changes of the sagittal spine disposition and pelvic tilt during standing and sitting.

Variable	Group	Pre-intervention (X $\pm$ SD)	Post-intervention (X $\pm$ SD)	F	p-value	η^2	Mean dif.	95% CI
Standing Thoracic curv. (°)	TG	56.81 $\pm$ 5.62	52.05 $\pm$ 6.72	47.949	< .001	0.432	-4.758	-3.385; -6.131
	CG	51.70 $\pm$ 8.40	51.88 $\pm$ 7.65	0.030	.863	<0.001	0.180	2.265; -1.904
Standing Lumbar curv. (°)	TG	-25.89 $\pm$ 8.46	-20.31 $\pm$ 10.56	15.460	< .001	0.205	5.574	8.409; 2.738
	CG	-26.08 $\pm$ 8.47	-25.16 $\pm$ 8.96	3.900	.053	0.058	0.914	1.839; -0.011
Standing Pelvic tilt (°)	TG	11.15 $\pm$ 8.15	5.06 $\pm$ 5.39	48.318	< .001	0.434	-6.086	-4.336; -7.836
	CG	8.89 $\pm$ 7.09	5.88 $\pm$ 5.70	8.601	.005	0.122	-3.008	-0.958; -5.058
Sitting Thoracic curv. (°)	TG	50.72 $\pm$ 6.49	49.44 $\pm$ 9.16	3.620	.062	0.054	-1.281	0.064; -2.627
	CG	46.72 $\pm$ 10.61	48.38 $\pm$ 9.54	2.342	.131	0.036	1.664	3.837; -0.509
Sitting Lumbar curv. (°)	TG	-5.80 $\pm$ 9.08	0.88 $\pm$ 11.22	49.930	< .001	0.442	6.672	8.559; 4.785
	CG	-5.98 $\pm$ 11.09	-4.92 $\pm$ 12.11	0.479	.491	0.008	1.063	4.130; -2.005
Sitting Pelvic tilt (°)	TG	1.40 $\pm$ 7.43	0.56 $\pm$ 7.06	0.552	.460	0.009	-0.844	1.426; -3.113
	CG	1.81 $\pm$ 7.52	1.75 $\pm$ 7.45	0.004	.951	<0.001	-0.063	1.945; -2.070

CG: control group; curv: curvature; TG: training group; Baseline intergroup difference post-randomization: * : $p < .05$; ** $p < .001$

Table 5. Inter-group changes of the sagittal spine disposition and pelvic tilt during standing and sitting.

Variable	Group	Diff. Post-pre (X±SD)	Mean dif.	p-value	95% CI (upper; lower limit)	F/Z	ES
Standing Thoracic curv. (°)	TG	-4.76±5.50	4.938	< .001	2.49;7.39	15.938	0.115
	CG	0.18±8.14					
Standing Lumbar curv. (°)	TG	5.57±11.07	4.660	.002	1.76;7.55	10.149	0.076
	CG	0.91±3.70					
Standing Pelvic tilt (°)	TG	-6.09±7.00	3.078	.024	0.41;5.74	5.222	0.040
	CG	-3.01±8.14					
Sitting Thoracic curv. (°)	TG	-1.28±5.39	2.945	.023	0.41;5.48	5.304	0.040
	CG	1.66±8.70					
Sitting Lumbar curv. (°)	TG	6.67±7.55	-5.609	.002	-9.18; -2.04	9.690	0.071
	CG	1.06±12.28					
Sitting Pelvic tilt (°)	TG	-0.84±9.09	0.781	.607	-2.22;3.78	0.265	0.002
	CG	-0.06±8.04					

CG: Control Group; curv: curvature; TG: Training Group; ES: Effect Size

Table 6. Differences in pre-post test changes between standing and sitting positions.

Variable	Position	Diff. Post-pre (X±SD)	Mean dif.	p-value	95% CI (upper; lower limit)	t	ES
Thoracic curvature (°)	Standing	-4.76±5.50	-3.48	<0.001	-4.81; -2.15	-5.23	0.63
	Sitting	-1.28±5.39					
Lumbar curvature. (°)	Standing	5.57±11.07	-5.76	<0.001	-7.59; -3.92	-6.27	0.12
	Sitting	0.91±3.70					
Pelvic tilt (°)	Standing	-6.09±7.00	-5.24	<0.001	-8.03; -2.45	-3.75	0.64
	Sitting	-0.84±9.09					

5.16. DISCUSSION

The main objective of the present investigation was to analyze the effect of a resistance training program using OFE on the sagittal spine disposition and pelvic tilt of middle-aged and older adults. The results showed a significant reduction in all curvatures of the sagittal spine disposition in the standing position of the TG after the intervention. In contrast, the CG showed no significant differences in thoracic or lumbar curvatures. In both thoracic and lumbar curvatures, as well as in pelvic tilt, the reduction in the TG was significantly greater than that of the CG.

In accordance with the findings of the current study, previous studies have shown that the systematic performance of multicomponent programs that include general resistance exercises, trunk muscle strengthening, joint mobility exercises, and stretches that target the muscles associated to the trunk, lead to a reduction in sagittal curvatures while in a standing position, following an 8-week training period (González-Gálvez et al., 2019; Jang et al., 2019; Jenkins et al., 2021). Similarly, a recent systematic review with meta-analysis concluded that structured physical exercise combining thoracic strength/stabilization, mobility, and flexibility, was an effective intervention for reducing the occurrence of thoracic hyperkyphotic curvatures. However, it suggested that utilizing a multicomponent approach may not be the most optimal strategy for maximizing the desired changes, as the studies reviewed were of low to moderate quality, and more studies on the subject were therefore needed (Jenkins et al., 2021).

The same trend is found in the older population, where most studies have analyzed the effects of a multicomponent intervention on spinal alignment (Jang et al., 2019; Jenkins et al., 2021). However, few studies have demonstrated the effect of a training program based exclusively on guided equipment-based resistance training on the reduction of the sagittal spine disposition in the standing position of middle-aged and older adults (Harding et al., 2021). In that study it was found that a full body work with guided machines can improve thoracic kyphosis, but that on the contrary, a poor selection of guided machines such as core pull and vertical lift exercises and their isometric execution can lead to vertebral fractures (Harding et al., 2021). Another study reported no significant differences, perhaps attributed to the low intensity of the strength program performed with elastic bands (Bergström et al., 2011). On the contrary, studies performed on

postmenopausal women and men over 45 years of age with a low bone mineral density found that after training similar muscle groups by means of exercises using 80–85% of one maximum repetition, a significant improvement of $-6.7 \pm 8.2^\circ$ and $-2.3 \pm 0.8^\circ$ respectively, of thoracic kyphosis was observed after eight weeks of training (Harding et al., 2021; Watson et al., 2019). In contrast, they did not report the effect size using eta squared, so it could not be compared. A previous review indicated that the key to generating changes in the sagittal disposition of the thoracic spine could lie on the volume of training and the selection of devices that provide a sufficient load, especially when the trunk musculature is worked in this type of circuit as a synergistic factor with the rest of the exercises (Bansal et al., 2014; Katzman et al., 2017). In light of the results of the present research, this also seems to be the case with OFE, which could provide a sufficient stimulus to generate adaptations in the spine.

The analysis of the sagittal disposition of the spine in the standing position is essential. It is the most used position especially in older people, due to the consequences it has on aspects such as balance and the probability of falling (Sinaki et al., 2005). It has been observed that an increase linearity can improve people's balance (Choi et al., 2011; Sinaki et al., 2005), and therefore, in our case, the improvement in linearity after training could reduce the risk of falling.

The reduction in sagittal curvatures and pelvic tilt in the standing position after resistance training found in the present study could be due to the fact that during the training session, different strengthening exercises were performed, where the trunk musculature was involved as an agonist or synergist, especially the paravertebral muscles, spinal erectors, latissimus dorsi, rhomboids, and the upper back. In addition, the pectoral and shoulder musculature were involved to improve the function of these muscles and to gain a greater range of joint mobility, with these factors associated with a lower thoracic hyperkyphosis (Abelleira-Lamela et al., 2024b; Karimizadeh et al., 2022). Previous studies have found that trunk musculature exercises are essential for the correction of spinal misalignments (Abelleira-Lamela et al., 2021; González-Gálvez et al., 2019; Karimizadeh et al., 2022; Ponzano et al., 2021), which in addition to the results presented in this work, demonstrates that the effects of this type of training can also be extrapolated to the older population. Considering the high incidence of hyperkyphosis and hyperlordosis in this population (Pai et al., 2021), and their consequences on

different areas of health (Wong et al., 2017), resistance training could be a great resource that could be used by the older population to reduce the incidence of these pathologies (Wong et al., 2017). In addition, it has been proven that its effect lasts over time; studies in which the strengthening of the spinal extensors was performed, along with other types of exercise, showed that hyperkyphotic women maintained improvements in kyphosis, spinal extensor strength, and physical performance one year after the intervention (Pawlowsky et al., 2009). Another study based on a 3-month intervention using low-load training and elastic bands found that 3 years after the intervention, sagittal spine curvatures did not worsen with ageing (Katzman et al., 2021). For this reason, training by means of OFE, which in young people has been proven to provide a stimulus similar to low loads (Abelleira-Lamela et al., 2024b, 2024a), may involve a greater effort in adults, generating an intensity that may result in benefits on the sagittal spine disposition that are maintained over time, with this becoming a topic to be studied in future research.

One of the novelties of the present study was that it assessed the influence of training on the sagittal spine disposition and pelvic tilt also in the sitting position. Sitting is one of the most commonly used positions for spine analysis. It is important to analyze the disposition in this body position in older adults, as this population usually spends long periods sitting, up to 60% of their waking time (Matthews et al., 2008). It has been shown that the sitting position produces greater intradiscal pressure than when standing, and that the loss of spinal linearity further increases the stress on the annulus fibrosus, nucleus pulposus, and cortical bone (Cho et al., 2023). Other studies also found that greater lumbar flexion increased intradiscal pressure and antero-posterior compressive and shear stress, which together with prolonged sedation with an inversion of the lumbar spine, increases the capacity for intervertebral flexion due to the viscoelastic deformation of the ligaments of the posterior arch of the vertebrae (López-Miñarro et al., 2014). It is for this reason that poor ergonomic positions when sitting can compromise the inversion of the lumbar area to a greater extent, and increase the laxity of the thoracolumbar ligament, which can lead to acute deformations, or chronic ones in the case of being maintained over time, as in the case of the older people and the long periods of time spent sitting (Matthews et al., 2008). These aspects may influence the health of middle-aged and older adults (Hrysomallis & Goodman,

2001). For all of these reasons, previous studies have pointed out that it is necessary to analyze the sagittal spine disposition and pelvic tilt in different positions, beyond the exclusive evaluation in the standing position (Pai et al., 2021).

Previous studies showed that OFEs force their users to adopt certain postures with the sagittal spine disposition and pelvic tilt involved during their use (Abelleira-Lamela et al., 2021), but this is the first study to verify the effects of their continued use. In the present study, when sitting, a decrease in lumbar lordosis was found in the TG, with a greater disposition in the participants who performed the resistance work as compared to those who did not train. The results found, such as those in the standing position, could be due to the fact that the implementation of a muscle strengthening program reduces the incidence of spinal misalignments (Dimitrijević et al., 2022; González-Gálvez et al., 2019; Jang et al., 2019; Ponzano et al., 2021), although this is the first study to demonstrate that this improvement in spinal alignment goes beyond the standing position. In light of these results, resistance training in middle-aged and older adults could improve the sagittal spine disposition in both standing and sitting positions, and may also result in less disc tension (Cho et al., 2023) and viscoelastic deformation of the ligaments of the posterior arch of the vertebrae (López-Miñarro et al., 2014).

This study also compared the evolution of the curvatures in standing and sitting positions. It was found that the changes produced in the spine through training with OFE were observed, to a greater extent, in the standing position than in the sitting position. The standing position depends to a great extent on muscular tolerance (Ghamkhar & Kahlaee, 2019; Larson & Brown, 2018). Previous studies have suggested that low muscle tolerance of the extensor and stabilizing muscles of the trunk is related to poorer postural hygiene in standing (Ghamkhar & Kahlaee, 2019; Larson & Brown, 2018). This could be because, as these muscles fatigue, the latency of muscle activation increases, and fewer bundles of muscle fibers are activated (Fitts, 1994; Larson & Brown, 2018). This leads to less muscular opposition to the effect of gravity, resulting in misalignments from the sagittal spine disposition (O'Sullivan et al., 2002). Muscle tolerance can be modified with training (Ghamkhar & Kahlaee, 2019; O'Sullivan et al., 2002). More specifically, previous studies have found that resistance training with machines, by generating an activation of the stabilizing muscles of the trunk as synergists maintained over time, increases the muscular tolerance of these muscles (Stevens et al., 2008). This

could lead to greater tolerance of these muscles in their tonic function of maintaining adequate postural hygiene when standing, improving the sagittal spine disposition in this position (O'Sullivan et al., 2002).

On the contrary, the sitting position usually depends directly on postural hygiene and more specifically the pelvis disposition (Aramaki et al., 2021; Frey et al., 2019). Previous studies have suggested that the pelvis tilt is the main factor determining factor for the sagittal spine disposition in a sitting position (Aramaki et al., 2021; Frey et al., 2019). This could lead to the tolerance of the extensor muscles of the trunk having less influence on the sagittal spine disposition in this position (Kett et al., 2021). Therefore, programmes that only work on muscle strengthening, as is the case with the present intervention, could have little effect on the sagittal spine disposition when sitting. And the fact is that, unlike other studies, the focus of this intervention was not the direct work on postural hygiene but the strengthening of the musculature.

Because of all of the above, the improvement of the sagittal spine disposition in sitting position could depend on the ergonomics and postural hygiene of the person rather than on other intrinsic aspects such as muscle tolerance (Szczygieł et al., 2017). On the other hand, the changes could depend more on muscle tolerance in standing (Ghamkhar & Kahlaee, 2019; Larson & Brown, 2018). This could explain why changes shown in the present research are reflected to a greater extent in the relaxed standing position. However, in the absence of previous studies that analyzed the effects of strength training on the sagittal spine disposition in both standing and sitting positions in older people, further studies on this topic are needed.

Regarding the clinical relevance of the changes found in the current study, previous studies showed that an improvement of 2.8° in the thoracic curvature angulation was relevant from a clinical point of view (González-Gálvez et al., 2021). Therefore, since the changes produced by the training were greater than 2.8° of angulation, OFE are deemed as an effective means to achieve an alignment of the sagittal spine disposition. In addition, given that the angle of kyphosis thoracic can increase by 2.6° in three years, 3.9° in four years, and 7° in fifteen years in elders (Koelé et al., 2020); a reduction close to 5°, as was found in the present investigation, could be considered not only a method of restraining the effects of the passage of time, but also an improvement with respect to the change due to ageing. These

improvements could bring benefits such as improved balance, a reduced risk of falling, an improved respiratory capacity, increased mobility, reduced back pain, and reduced pain in the entire back (Ailon et al., 2015; Arja et al., 2003; Choi et al., 2011; Imagama et al., 2013; Sinaki et al., 2005; Wong et al., 2017). On the other hand, an intervention of longer duration with OFE could obtain better results, so it would be important to analyze this in future studies.

In summary, it can be observed that OFE can provide a sufficient stimulus to improve spinal curvatures in the standing position, but with a lesser effect in the sitting position after an 8-week intervention. On the other hand, these machines demonstrated their ease-of-use with the older population, achieving a high adherence by the participants. In addition, the availability of OFE facilities in multiple parks makes it possible for older people to train on their own, following the training schedule pattern used in the present research, which could improve the sagittal spine disposition in this population in light of the results of the present research. Nevertheless, there are also some barriers, such as the possible poor condition of public OFE due to banditry, as well as the dependence on the weather for their use. In addition, the lack of knowledge on the proper way to train with this type of machine can lead to their inadequate or inefficient use (Chow et al., 2017).

Regarding the effect size, this study obtained an eta squared of 0.432 in the variable thoracic curvature in relaxed standing position after the intervention performed using OFE. It was found that interventions which consisted of a program of strength, mobility and postural training exercises specifically designed to treat hyperkyphosis in older adults with a similar distribution of training, with two weekly sessions of one hour for 3 months, showed similar value (effect size: 0.419) in the kyphosis variable in standing (Katzman et al., 2017). Another study focused on the training of people over 65 performed for 6 months two types of training, one aimed at the extensor muscles of the back and another group that performed an exercise program for the whole body, both using their own body weight and increasing the load with elastic bands or light weights, performing at least a seminal session of between 20 and 30 min (Fukuda et al., 2020). The results contrasted with those presented in this article, since even though the effect size on thoracic kyphosis was greater in the group that did back extensor strengthening protocol with respect to the OFEs (0.62 vs 0.432), in lumbar curvature and pelvic

tilt the OFEs obtained a greater or similar effect respectively ES (0.19 vs 0.205 and 0.06 vs 0.434, respectively) with an intervention of only 8 weeks.

Despite the novelty of the present research, it is not without limitations. The first limitation of the present study was the sample size, although it was larger than that found in similar studies (Bergström et al., 2011; Jenkins et al., 2021). In addition, although participation was not limited, a greater number of female volunteers was present, while the male sample was relatively small. Therefore, it was not possible to analyze differences in the effects of resistance training as a function of sex. Therefore, the present results should be extrapolated with caution and may not be extrapolated to populations other than the one presented in this study. In this line, future studies are needed to analyze whether the effect of OFE training on sagittal spine disposition in elders could be influenced by gender. On the other hand, at the time of blinding, due to the design of the study, it could not be applied to the researchers who conducted the training sessions. Another limitation was that the OFE does not allow the external load to be regulated, as they are mostly machines that work with the user's own body weight. Therefore, the evolution of training could not be based on an increase in load, which could be a future line of research. On the other hand, in the current study, the control group maintained their usual lifestyle, and they did not carry out any systematic training. Therefore, there was no traditional machine training group. As a consequence, the design of the present investigation did not analyze whether the effects of OFE training on sagittal spine disposition and pelvic tilt may differ from those achieved with conventional resistance training with gym equipment. This precluded determining the strength of the effects of OFE with respect to other machines, but even so, their effect was tested in comparison with the usual life of the control population. This is an important line for future studies.

Based on these limitations and according to the findings of the present study, a recommendation is given to analyze and compare different population groups with special emphasis on differentiation, taking into account the age and the gender of the subjects. It will also be important to perform both standing and seated measurements and to include a comparative analysis. In addition, the use of OFE in interventions where it is combined with other types of exercises, such as stretching or other exercises aimed at improving balance, could enrich our knowledge on OFE. And having a training group with traditional machines in

order to compare the strength of the OFE effect could provide more information. Another type of intervention proposed for future research is one in which the load on the OFE can be regulated in order for this factor to be taken into account. Finally, for these interventions, their long-term effects must also be assessed.

5.17. CONCLUSIONS

After 8 weeks, at a rate of two sessions per week of circuit resistance training with OFE, a better alignment of the thoracic and lumbar spine and pelvic tilt in the standing position was found in middle-aged and older adults. The lumbar curvature in the sitting position was also found to be improved after the training program. These results suggest that programmed training using OFE can be a useful tool for the improvement of the health of older adults, specifically their spine, with only two weekly sessions of circuit resistance training.

The findings of this study highlight the potential for OFE to serve as an accessible and effective tool for improving spinal spine disposition and pelvic tilt among older adults and to reduce age-related spinal misalignments. Communities and policymakers can use these insights to promote health by integrating OFE into public parks and recreational areas, creating safe and well-maintained spaces for older populations to engage in resistance training. Additionally, offering training sessions or reading materials on how to use OFE effectively may address barriers such as a lack of knowledge and ensure proper ergonomic postures.

**ESTUDIO 4: ELECTROMYOGRAPHIC
COMPARISON OF TRADITIONAL
FITNESS MACHINE, OUTDOOR
FITNESS EQUIPMENT WITHOUT LOAD
SELECTOR, AND OUTDOOR FITNESS
EQUIPMENT WITH LOAD SELECTOR IN
SEATED CHEST PRESS EXERCISE IN
TRAINED YOUNG MEN**

Va – ESTUDIO 4: Electromyographic Comparison of Traditional Fitness Machines, Outdoor Fitness Equipment Without Load Selectors, and Outdoor Fitness Equipment with Load Selectors in a Seated Chest Press Exercise in Trained Young Men

5.18. ABSTRACT

Outdoor fitness equipment (OFE) are strength training installations comparable to those found in indoor gyms but are located outdoors with greater accessibility. However, the scientific evidence supporting their effectiveness remains limited. The objective of this study was to analyze and compare the electromyographic (EMG) activity of upper limb muscle groups during the use of a traditional seated chest press (SCP) machine, a classic OFE SCP (OFE-SCP), and a new OFE SCP featuring a load selector system (BIOFIT-SCP). The sample was composed of 34 active young men. EMG activity of five muscle groups was analyzed: the anterior deltoid (AD), the clavicular (CP) and sternal (SP) heads of the pectoralis major, and the lateral (LHTB) and long heads of the triceps brachii (LongHTB), under different intensities. The OFE-SCP showed significantly lower EMG activity compared with the SCP and BIOFIT-SCP in all muscles and phases ($p < .001$). Significantly lower EMG activity for the SP in all three phases was found on the BIOFIT-SCP compared with the SCP ($p < .001$), but it was significantly higher for the LHTB and AD in the BIOFIT-SCP compared with the SCP during the full and concentric phases ($p < .05$ to $p < .001$). In conclusion, training with the OFE-SCP generates less EMG activity than traditional machine training, while, in general, BIOFIT-SCP proved effective for strength training comparable to the SCP.

5.19. INTRODUCTION

Strength training is becoming increasingly popular in the population thanks to the health benefits it brings to its practitioners (Armstrong et al., 2022; Martín-Fuentes et al., 2020b). Muscle mass gains and increased strength levels are the main objectives of most users who practice it (Armstrong et al., 2022; Escamilla et al., 2001). Multiple training methods and tools can be used to train for strength, with guided machines being one of the most widely used (Muyor et al., 2023).

However, in recent years, outdoor fitness equipment (OFE) has become popular as a more accessible alternative to guided machines in a fitness room (Chow & Ho, 2018; Jansson et al., 2019). These are known as sports equipment that are operated in a manner similar to traditional gym machines, although they are commonly located in public outdoor spaces such as parks (Abelleira-Lamela et al., 2021; Chow & Wu, 2019; Jansson et al., 2019). Despite the popularity of OFE and the economic investment made for their installation and maintenance, there is some controversy regarding their effectiveness. In this line, while some studies indicate that training with OFE could improve body composition and strength production capacity in older adults (Marcos-Pardo et al., 2024), as well as improve physical functionality in seniors (Chow et al., 2021); other studies indicate that training with this equipment may not be effective in adults and older adults, as a result of the reduced training intensity involved (Chow et al., 2017; Liu et al., 2020). This is because traditional OFE are limited to working with one's own body weight (Liu et al., 2020), so they do not allow for a controlled intensity progression within training sessions. Therefore, new models are emerging that allow the user to regulate the external load through a system that can be used to increase the weight, similar to that of traditional fitness room guided machines (Abelleira-Lamela et al., 2024a; Marcos-Pardo et al., 2024).

In recent years, machines that allow for pushing-based exercises in a guided manner have increased in popularity and can be found in both traditional guided machine training facilities (Haugen et al., 2023) and OFE (Chow & Ho, 2018). This is because these types of machines have been seen as an alternative to the use of free weights and can provide the same results but with greater safety and less reliance on exercise technique control (Haugen et al., 2023). Their use is common for both aesthetic purposes and to strengthen the upper body musculature, which is essential for performing daily tasks such as lifting or pushing objects (Hik & Ackland, 2019).

Along this line, several previous studies have analyzed the efficacy of the seated chest press (SCP) machine by performing a surface electromyographic analysis (EMG) of the activation of the upper limb musculature during its execution (Coratella et al., 2019; López-Vivancos et al., 2023; Muyor et al., 2023; Signorile et al., 2017). The choice of the SCP machine was made because it is one of the most popular guided machines for push-work in fitness (Trebs et al., 2010). These studies

have shown that the SCP is an effective machine for activating the main muscle groups involved in these pushing exercises, such as the anterior deltoid, the pectoralis major, and the triceps brachii (Cacchio et al., 2008; Coratella et al., 2019; López-Vivancos et al., 2023).

In turn, within most OFE machine lines, SCP machines (OFE-SCP) are also included. However, so far, no studies have been found that analyze the effectiveness of OFE-SCP machines in terms of muscle activity of the *a priori* involved musculature. Therefore, for practical purposes, it is not known whether this machine could be effective in achieving adaptations in upper limb muscles after training with it. There is, however, a previous study that compared the EMG between traditional leg machines and the OFE leg machine, finding that, in general terms, the OFE showed less activation of the muscles involved in the lower limbs, which could be because it only allows working with one's own weight (Abelleira-Lamela et al., 2024a).

Likewise, it has not been empirically proven whether the inclusion of an adjustable external weight in the OFE can improve the effectiveness of SCP machines. Only one previous study compared the EMG readings between a traditional guided leg machine and an OFE that allowed external weight adjustment, finding that at a similar intensity as a percentage of 1RM, a similar activation of the main lower limb musculature occurred, although the activation of the synergist musculature varied slightly because of the biomechanical differences between the exercises performed (Abelleira-Lamela et al., 2024a).

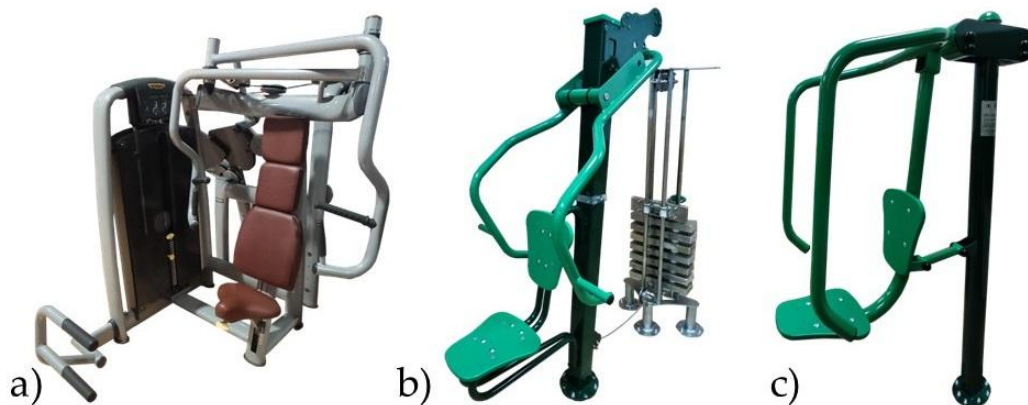
Therefore, the main objective of the present investigation was (a) to analyze and compare the EMG recorded in the upper limb muscle groups during the use of a SCP, OFE-SCP, and a push machine belonging to a new line of OFE that allows the external load to be regulated (BIOFIT-SCP); and (b) to determine the differences in the EMG of the upper limb muscle groups at 60 and 75% of 1RM in the SCP and BIOFIT-SCP machines. In relation to the hypothesis, it was proposed that: (a) the EMG of the upper limb musculature will be similar between the machines that allow the external load selection (SCP and BIOFIT-SCP), and activation will be greater in SCP and BIOFIT-SCP machines compared with a machine that only allows working with one's own body weight (OFE-SCP); and (b) the EMG recorded will be greater at 75% of 1RM than in 60% of 1RM in SCP and BIOFIT-SCP machines.

5.20. MATERIALS AND METHODS

5.20.1. Design

This research consisted of a randomized cross-sectional study. The 1RM was calculated on the SCP (Figure 1a) and the new BIOFIT seated chest press (BIOFIT-SCP), which is an OFE that has an external weight selector (Figure 1b). The calculation of the 1RM from each of the machines was done in a different session (session one and session two). Furthermore, the EMG activity of five muscle groups (anterior deltoid (AD), clavicular (CP) and sternal (SP) heads of the pectoralis major, and the lateral (LHTB) and long head of the triceps brachii (LongHTB)) was analyzed on three different types of chest press machines, i.e., SCP, OFE-SCP, and BIOFIT-SCP in another session (session three). In the SCP and BIOFIT-SCP machines, an EMG activity analysis was performed at 60 and 75% of the 1RM, while in the OFE-SCP machine, the analysis was performed with the subject's own body weight. A period of 72 h was given between each of the evaluation sessions of each participant. The study utilized a specific research model, as illustrated in Table S1.

Figure 2. Fitness equipment used. (a) Seated chest press (SCP) (Technogym; Cesena, Italia); (b) outdoor fitness equipment seated chest press with selectorized system (OFE-SCP) (Entorno Urbano, Murcia, Spain); (c) outdoor fitness equipment seated chest press (BIOFIT-SCP) (Entorno Urbano, Murcia, Spain).



The machines selected for this research were: a machine commonly used in the fitness industry, the SCP model (Technogym; Cesena, Italy), with external load adjustment via a selectorized system (Escamilla et al., 2001) (Figure 1a); a machine belonging to a new line of OFE called BIOFITSCP (Entorno Urbano, Murcia, Spain),

which allows the external load adjustment by means of a selectorized system (Escamilla et al., 2001), and which is patented (Patent registration for the OFE-SCP at the Spanish Patent and Trademark Office, application number: ES1296848Y; and patent registration for the external load selector, Spanish Patent and Trademark Office application number: P202231017) (Figure 1b); and a classic OFE machine line, corresponding with the same machine model, the Gemini (OFE-SCP) (Entorno Urbano, Murcia, Spain), which uses the user's body weight as the external weight (Chow et al., 2021) (Figure 1c).

This research was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the institutional ethics committee (Ethical Approval Reference: CE111908). Before starting the study, all volunteers were informed about the different types of tests and voluntarily signed an informed consent form to participate in the present investigation.

5.20.2. Participants

A methodology utilizing the standard deviation (SD) was employed to determine the sample size (Bhalerao & Kadam, 2010). For this analysis, RStudio version 3.15.0 was utilized. The calculations for sample size and statistical power were conducted based on the standard deviation of the variable peak pectoralis major EMG activity during the use of a SCP selectorized plate machine ($SD = 63.82 \mu V$) demonstrated by a sample of physically active young adults ($n = 15$) (Signorile et al., 2017). An estimated error (d) of $32.30 \mu V$, along with a 95% confidence interval (95% CI), a statistical power of 95%, and a significance level of 0.05, indicated that a minimum of 34 participants was required for the study.

The study included a total of 34 male participants (mean age = 21.54 ± 1.80 years old; mean stretch stature = 176.62 ± 6.67 cm; mean body mass = 74.27 ± 9.99 kg). The inclusion criteria were: (1) being male, (2) a minimum of 2 years of experience using gym machines for training, along with currently engaging in strength training with these machines at least three times per week, and (3) being within the age range of 19 to 24 years old. The exclusion criteria were: (1) engaging in physical activity within 48 h before the initial session or between assessment sessions (Trebs et al., 2010), (2) any recent injuries to the upper limbs or trunk

within the previous 6 months (Abelleira-Lamela et al., 2024a), and (3) present a diagnosed muscle abnormalities or joint conditions (Abelleira-Lamela et al., 2024a).

5.20.3. Measurements

5.20.3.1. Questionnaire

All the participants were asked to complete an ad hoc questionnaire on their sociodemographic characteristics, their experience in strength training, the use of guided machines, and possible injuries and pathologies suffered. This questionnaire was created based on previous studies (Abelleira-Lamela et al., 2024a).

5.20.3.2. Anthropometric Measurements

For the measurement of the anthropometric variables stretch stature and body mass, the indications from the International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al., 2019) were followed by an accredited ISAK level-2 anthropometrist. An HR001 portable stadiometer (Tanita, Arlington Heights, IL, USA) and a Tanita BC-545N scale (Tanita, Arlington Heights, IL, USA) were used. The variables were measured twice or three times if the difference between the first two was greater than 1%, with the final value being the mean or median, respectively.

5.20.3.3. Assessment of 1RM

The 1RM was calculated in the SCP and BIOFIT-SCP machines. The OFE-SCP was discarded for this test because it does not have any external weight control system (Liu et al., 2020). The order of use of the SCP and BIOFIT-SCP machines to determine the 1RM in each machine was randomized. The protocol recommended by the National Strength and Conditioning Association (Miller, 2012) was utilized for the calculation of 1RM in both machines. The participants performed a warm-up, comprised of a set with an intensity that allowed them to complete between 5 and 10 repetitions. Following a 1 min rest period, the intensity was increased by 10 to 20%, at which point they were required to perform at least three but no more than five repetitions. Following a 2 min rest period, the intensity was increased again by 10 to 20%. At this new intensity, participants were required to complete

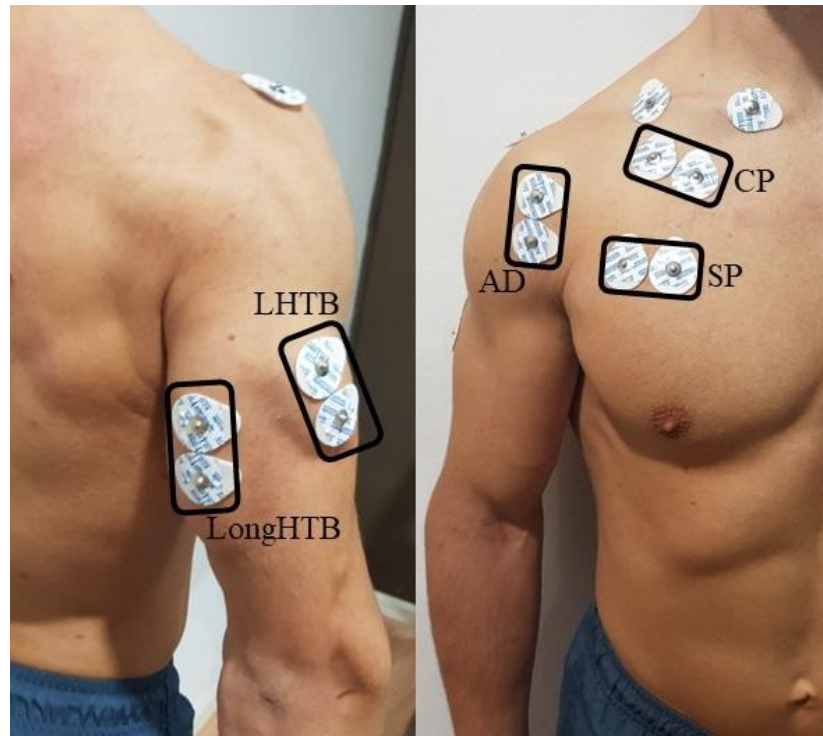
between two and three repetitions. After this, the intensity was adjusted upward by 10 to 20% for a single repetition attempt. Depending on whether the lift was successfully completed, the load was either increased or decreased by 5 to 10%, repeating this process until the 1RM was identified. A maximum of five attempts at varying intensities were performed, with four minutes between each attempt (Miller, 2012). A total of 72 h later, the protocol was repeated to determine the 1RM on the other machine, following the prior randomization.

5.20.3.4. *Electromyographic (EMG) Analysis*

Seventy-two hours after the second 1RM calculation session, the EMG signal was recorded in AD, CP, SP, LHTB, and LongHTB. The subjects performed, in a randomized order, five repetitions in the SCP machine with intensities of 60 and 75% of 1RM, five repetitions in the BIOFIT-SCP machine with intensities of 60 and 75% of 1RM, and five repetitions in the OFE-SCP machine with their own weight. This protocol followed the procedure of previous studies (Abelleira-Lamela et al., 2024a; Duffey & Challis, 2007). These intensities were selected for the SCP and BIOFIT-SCP machines as they are commonly used in different guided machines training methods (Abelleira-Lamela et al., 2024a; López-Vivancos et al., 2023).

The electrodes were arranged according to the recommendations from the Surface Electromyography for the Non-invasive Assessment of Muscles (SENIAM) project (Stegeman & Hermens, 2007). The areas where they were placed were shaved and cleaned with 96% alcohol and sterile gauze to avoid possible erroneous signals and reduced skin impedance (Snarr & Esco, 2013). The gel electrodes used were placed at a 2 cm center-to-center distance in the longitudinal direction of the muscle fibers (Stegeman & Hermens, 2007). Following the methodology from previous studies, bilateral symmetry was assumed during exercise execution, so all electrodes were located on the right side of the body in a standardized manner (Snarr & Esco, 2013). The parts recorded were CP, SP, LHTB, LongHTB, and AD (Figure 2). EMG activity was recorded during exercise using the MuscleLab Surface electromyography system (Ergotest Innovation AS, Stathelle, Norway) at a sampling rate of 1500 Hz.

Figure 2. Electrode location on the right arm. AD = anterior deltoid; CP = clavicular pectoralis; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; SP = sternal pectoralis.



5.20.4. Randomization and Blinding

The sequence of machine usage for the 1RM assessment, the order of machine use for EMG analysis, and the initial 1RM intensity for each machine during EMG analysis were all randomized following the methodology of previous studies (Schoenfeld et al., 2014). The procedure was conducted by the principal investigator in the presence of external researchers, utilizing a computer-generated random number table. All measurements were carried out following the randomization process.

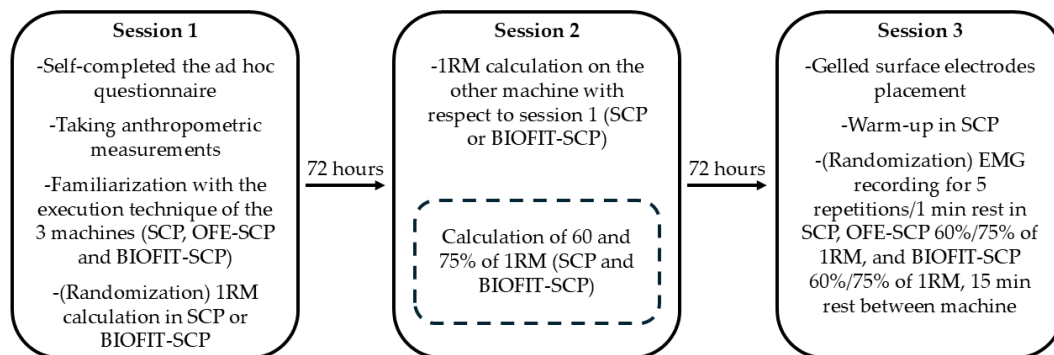
The researchers who performed the EMG measurements were not involved in the 1RM calculation tests. In the measurements of EMG, the two investigators involved in the data collection were also blinded transversely, where one controlled the exercise execution technique and provided the guidelines for the development of the protocol, while the other focused exclusively on verifying the

accuracy of the EMG data recording. This procedure was carried out following previous research (Abelleira-Lamela et al., 2024a).

5.20.5. Procedure

Figure 3 shows the procedures carried out during the three sessions in schematic form, following previous studies (Abelleira-Lamela et al., 2024a). In session one, the volunteers filled out the ad hoc questionnaire, followed by the anthropometric measurements. Subsequently, the essential guidelines for proper exercise execution on each of the three machines (SCP, OFE-SCP, and BIOFIT-SCP) were provided to ensure they were familiar with the required execution technique for each exercise to facilitate accurate data collection. Specifically, they were informed that exercises on the various machines should be performed using a full range of motion, from 90° elbow flexion to full extension. On the SCP machine, the seat was placed at height number 3 so that the height of the seat to the grips was the same as on the BIOFIT-SCP machine.

Figure 3. Flow diagram.



Subsequently, participants carried out the 1RM calculation procedure using either the SCP or BIOFIT-SCP machine, with the order of execution assigned randomly. In the second session, the procedure was repeated to assess the 1RM in the other machine. Using the data collected from this procedure, the intensities corresponding to 60% and 75% of the 1RM were subsequently calculated for each participant on both the SCP and BIOFIT-SCP machines.

In the third session, following electrode placement, participants completed a warm-up that included 12 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 8 repetitions at 70% of 1RM, and 2 repetitions at 90% of 1 RM on the SCP, as this

was the machine on which the participants had the greatest prior experience, similar to that reported in related studies (Abelleira-Lamela et al., 2024a; Andersen et al., 2018). EMG measurements were then initiated, with the assigned machine (SCP, OFE-SCP, or BIOFIT-SCP) selected randomly. For the SCP and BIOFIT-SCP machines, the intensity level (either 60% or 75% of 1RM) was also randomized. Participants were instructed to perform five repetitions on the initially assigned machine and intensity, maintaining a consistent speed throughout (Da Silva et al., 2008). A 1 min rest was taken between each repetition. After a 15 min rest, the same protocol was repeated on the same machine but using the other intensity. Once the full protocol was completed on the first machine, participants rested for 15 min before beginning the protocol on the second machine (Abelleira-Lamela et al., 2024a; Da Silva et al., 2008). In the case of OFE-SCP, a single set of five repetitions was carried out using the participant's body weight, following the same procedure, since the external load could not be modified (Chow et al., 2021; Jansson et al., 2019). Rest periods were established based on previous methodologies to prevent fatigue from impacting the results (Abelleira-Lamela et al., 2024a; Gonzalez et al., 2017).

For data analysis, all repetitions that had not been executed correctly from a technical point of view were discarded (Abelleira-Lamela et al., 2024a). The correct execution was considered to involve the following assumptions: (a) that the repetition was performed with a constant rhythm throughout the entire range of motion, without stopping, (b) that a full range of motion from 90° elbow flexion to full extension was involved, and (c) that the buttocks were in constant contact with the seat and the feet were resting on the floor during the entire execution (Mausehund et al., 2021).

The data analysis was conducted using the methodology outlined in a previous study (Da Silva et al., 2008). The first and last repetitions were excluded, and from the remaining three, the repetition with the highest root mean square (RMS) for the primary muscle group involved in the movement, the SP, was chosen, provided it was executed correctly. Data for all the muscles involved were recorded (Abelleira-Lamela et al., 2024a). The data were processed using MuscleLab v10.5.67 software (MuscleLab Ergotest Innovation AS, Norway) by converting the raw amplified EMG signals into RMS values (van den Tillaar et al., 2019). The RMS variable was measured during the entire repetition, as well as

separately for its concentric and eccentric phases, to enable comparisons between machines, consistent with previous studies (Albarelo et al., 2022). A MuscleLab twin-axis electrogoniometer (Ergotest Innovation AS, Stathelle, Norway) was utilized as a movement control variable to distinguish between the concentric and eccentric phases during exercise. The device was positioned on the participant's left arm, near the elbow joint, on the outer side. The distal sensor was aligned with the forearm, while the fixed sensor was aligned with the upper arm (Akima et al., 2021). Calibration was performed using a handheld goniometer set at 90° of elbow flexion while the participant maintained a stable, relaxed position. The point of maximum elbow extension was verified in situ, allowing differentiation of the concentric phase as the data captured from the initial 90° flexion to full elbow extension and the eccentric phase as the data collected from maximum extension back to 90° flexion. The full phase encompassed the analysis of the entire range of motion, beginning and ending at 90° flexion (Abelleira-Lamela et al., 2024a).

All measurement sessions were spaced 72 h apart to prevent any potential fatigue effects (Picerno et al., 2016). All participants were scheduled to attend each session at 8:00 a.m. (Abelleira-Lamela et al., 2024a). All measurements were conducted in the same room, under controlled conditions with a consistent temperature of 20 °C and a stable humidity level of 60%.

5.20.6. Statistical Analysis

Data analysis was conducted using SPSS software (Version 25; IBM Corporation, Armonk, NY, USA). The Kolmogorov-Smirnov test and Mauchly's W-test were applied to assess data normality. Mean values and standard deviations were computed. To compare muscle activation across different machines and intensities, a repeated-measures ANOVA with Bonferroni correction was conducted. To control for Type I error, Bonferroni's correction was applied, setting statistical significance at $p = .005$. A threshold of $p < .05$ was defined for acceptable error.

5.21. RESULTS

Table 1 shows the 1RM strength test results for the traditional SCP and BIOFIT-SCP machines.

Table 1. Results of the 1RM strength test.

	1RM	60% 1RM	75% 1RM
SCP (kg)	88.02±20.72	57.21±12.43	66.02±15.54
BIOFIT-SCP (kg)	44.51±15.06	26.71±9.04	33.38±11.30

1RM = one-repetition maximum; BIOFIT-SCP = BIOFIT seated chest press; SCP = traditional seated chest press.

Table 2 shows the mean and standard deviation of the root mean square recorded in each of the muscles analyzed when using the SCP at 60 and 75% of 1RM, the BIOFIT-SCP at 60 and 75% of 1RM, and the OFE-SCP with their own weight. The muscle group that showed a greater RMS was the AD during the concentric phase and the LHTB during the eccentric phase, except for the OFE-SCP, in which the AD muscle group showed a higher activation in both phases. With respect to the complete phase, the highest activations were observed in both the AD and LHTB, with the most notable being those recorded in the BIOFIT-SCP. Regarding the pectoralis, it was observed that CP presented a greater activation than SP in the two types of OFE (BIOFIT-SCP and OFE-SCP), while in the SCP, the greatest activation was presented by SP. In the triceps, LHTB presented the highest activation in the three machines and during the three phases analyzed compared with the LongHTB.

Table 2. Root mean square recording of the electromyographic signal in the different machines with different 1RM intensities.

	SP (M±SD)	CP (M±SD)	LongHTB (M±SD)	LHTB (M±SD)	AD (M±SD)
Complete					
SCP 60%	324.27±173.47	294.47±163.67	223.78±138.17	377.78±167.07	395.81±181.21
SCP 75%	388.32±195.96	348.72±174.16	298.41±153.99	483.80±213.02	475.87±216.16
BIOFIT-SCP 60%	170.39±104.46	294.61±135.61	240.59±76.97	477.74±209.51	491.45±236.06
BIOFIT-SCP 75%	242.52±140.62	345.74±158.54	293.61±92.29	562.39±231.58	565.45±256.92
OFE-SCP	92.13±48.52	131.16±52.86	118.06±43.67	233.81±97.10	282.89±134.02
Concentric					
SCP 60%	405.24±214.63	354.11±174.17	276.03±151.85	449.94±203.93	492.81±221.87
SCP 75%	464.00±231.01	400.29±185.58	357.95±154.14	556.01±241.40	570.43±258.28
BIOFIT-SCP 60%	228.02±137.01	373.41±168.02	314.12±96.52	606.76±249.69	641.30±290.93
BIOFIT-SCP 75%	310.05±174.62	415.49±179.38	362.90±110.13	675.58±269.82	709.09±316.85
OFE-SCP	108.66±58.08	150.04±62.60	141.33±65.01	277.29±140.53	344.46±156.46
Eccentric					
SCP 60%	218.49±130.02	211.61±149.48	160.86±136.70	293.15±152.20	277.87±141.80
SCP 75%	279.58±145.02	271.33±166.85	220.94±163.04	382.85±183.09	355.95±167.18
BIOFIT-SCP 60%	72.34±53.03	171.94±90.23	146.97±63.24	294.86±130.77	275.66±173.07
BIOFIT-SCP 75%	110.50±80.07	216.06±115.29	190.81±81.11	377.98±148.77	340.04±184.52
OFE-SCP	65.07±30.76	103.21±43.51	87.98±35.07	177.75±78.50	196.61±113.77

AD = Anterior deltoid; BIOFIT-SCP = BIOFIT Seated Chest Press; CP = Clavicular pectoralis; LHTB = Lateral head of the triceps brachii; LongHTB = Long head of the triceps brachii; OFE-SCP = Classic OFE; SCP = Seated Chest Press; SP = Sternal pectoralis.

Tables 3–5 and Figure 4 show the differences between machines and between different intensities in the full execution, concentric phase, and eccentric phase, respectively. At the same percentage of 1RM (60% 1RM vs. 60% 1RM, or 75% 1RM vs. 75% 1RM), the SCP presented a significantly greater activation of the SP in the three phases of execution ($p < .001$) and of the CP in the eccentric phase during execution at 75% of 1RM ($p < .05$) with respect to the RMS recorded in the BIOFIT-SCP. In the other phases and intensities, the CP did not present significant differences ($p > .05$). On the other hand, both LHTB ($p < .01$) and AD ($p < .05$) showed significantly higher activations in the full and concentric phases during the use of the BIOFIT-SCP with respect to the SCP at similar intensities, with no differences in the eccentric phase ($p > .05$). No difference in LHTB was found between SCP and BIOFIT-SCP at equal intensity ($p > .05$).

Table 3. Differentiation of peak electromyographic activity between different machines and intensities of 1RM during full execution.

	Complete repetition	SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	-64.05±7.33 [†]	153.88±19.24 [†]	81.75±19.47**	232.14±25.54 [†]
	SCP 75%		-	217.93±21.28 [†]	145.80±19.93 [†]	296.19±29.60 [†]
	BIOFIT-SCP 60%			-	-72.13±8.12 [†]	78.26±15.25 [†]
	BIOFIT-SCP 75%				-	150.39±21.45 [†]
	OFE-SCP					-
Clavicular pectoralis	SCP 60%	-	-54.25±6.35 [†]	-0.14±15.64	-51.26±16.01*	163.31±25.98 [†]
	SCP 75%		-	54.11±17.22*	2.98±16.46	217.55±27.62 [†]
	BIOFIT-SCP 60%			-	-51.12±7.24 [†]	214.57±25.44 [†]
	BIOFIT-SCP 75%				-	214.57±25.44 [†]
	OFE-SCP					-
LongHTB	SCP 60%	-	-74.63±8.21 [†]	-16.82±21.09	-69.83±22.03*	105.71±21.92 [†]
	SCP 75%		-	57.81±23.17	4.80±23.21	180.34±23.96 [†]
	BIOFIT-SCP 60%			-	-53.01±5.43 [†]	122.53±10.59 [†]
	BIOFIT-SCP 75%				-	175.54±13.57 [†]
	OFE-SCP					-
LHTB	SCP 60%	-	-106.02±12.90 [†]	-99.96±17.90 [†]	-184.62±22.30 [†]	143.97±17.26 [†]
	SCP 75%		-	6.06±17.69	-78.60±17.92**	249.99±23.80 [†]
	BIOFIT-SCP 60%			-	-84.66±9.72 [†]	243.92±25.18 [†]
	BIOFIT-SCP 75%				-	328.58±28.63 [†]
	OFE-SCP					-
Anterior deltoid	SCP 60%	-	-80.06±13.14 [†]	-95.64±25.48**	-169.64±27.18 [†]	112.92±22.97 [†]
	SCP 75%		-	-15.58±25.56	-89.58±25.83*	192.98±28.10 [†]
	BIOFIT-SCP 60%			-	-74.01±8.27 [†]	208.56±32.78 [†]
	BIOFIT-SCP 75%				-	282.56±36.24 [†]
	OFE-SCP					-

BIOFIT-SCP = BIOFIT Seated Chest Press; LHTB = Lateral head of the triceps brachii; LongHTB = Long head of the triceps brachii; OFE-SCP = Classic OFE; SCP = Seated Chest Press; * = *p* value < .05; ** = *p* value < .01; [†] = *p* value < .001.

Table 4. Differentiation of peak electromyographic activity between different machines and 1RM intensities during the concentric phase.

Concentric phase		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	-58.76±8.28 †	177.22±23.83 †	95.19±24.31**	296.58±32.02 †
	SCP 75%		-	235.98±24.57 †	153.95±23.43 †	355.34±35.23 †
	BIOFIT-SCP 60%			-	-82.03±9.70 †	119.36±20.10 †
	BIOFIT-SCP 75%				-	201.39±26.60 †
	OFE-SCP					-
Clavicular pectoralis	SCP 60%	-	-46.19±8.71 †	-19.30±17.99	-61.38±18.61*	204.06±28.57 †
	SCP 75%		-	26.88±20.15	-15.20±18.40	250.25±30.34 †
	BIOFIT-SCP 60%			-	-42.08±10.12**	223.37±28.25 †
	BIOFIT-SCP 75%				-	265.45±30.12 †
	OFE-SCP					-
LongHTB	SCP 60%	-	-81.92±10.20 †	-38.09±20.47	-86.88±22.06**	134.70±22.52 †
	SCP 75%		-	43.82±20.25	-4.96±20.38	216.61±21.79 †
	BIOFIT-SCP 60%			-	-48.78±6.19 †	172.79±13.90 †
	BIOFIT-SCP 75%				-	221.57±16.35 †
	OFE-SCP					-
LHTB	SCP 60%	-	-106.07±15.19 †	-156.82±19.44 †	-225.63±23.34 †	172.65±19.97 †
	SCP 75%		-	-50.75±19.10	-119.56±17.23 †	278.72±24.40 †
	BIOFIT-SCP 60%			-	-68.82±11.79 †	329.47±28.76 †
	BIOFIT-SCP 75%				-	398.29±31.03 †
	OFE-SCP					-
Anterior deltoid	SCP 60%	-	-77.62±15.64 †	-148.49±29.17 †	-216.28±31.89 †	148.35±29.06 †
	SCP 75%		-	-70.87±29.33	-138.66±30.74**	225.96±32.72 †
	BIOFIT-SCP 60%			-	-67.79±11.52 †	296.84±39.90 †
	BIOFIT-SCP 75%				-	364.62±43.89 †
	OFE-SCP					-

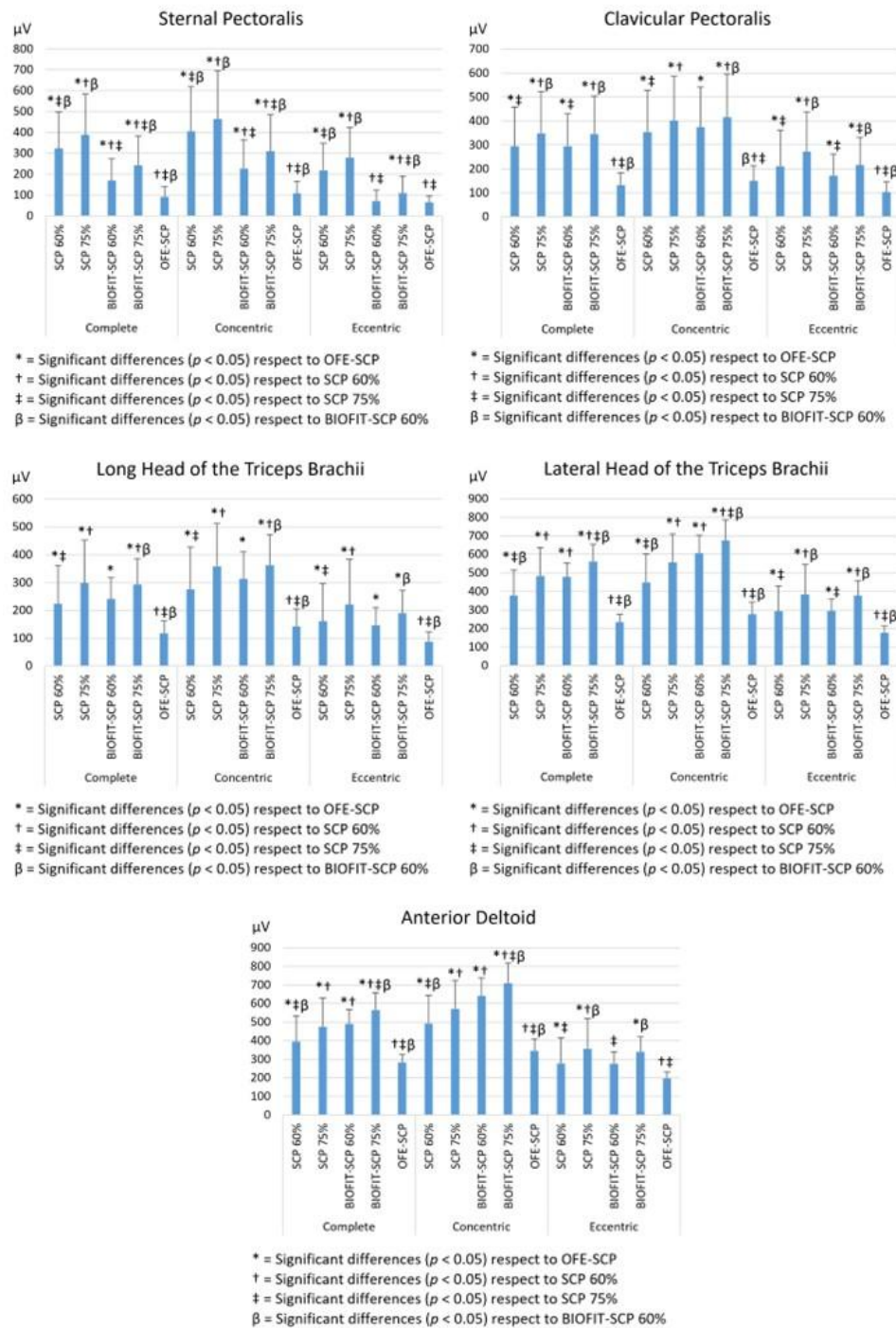
BIOFIT-SCP = BIOFIT Seated Chest Press; LHTB = Lateral head of the triceps brachii; LongHTB = Long head of the triceps brachii; OFE-SCP = Classic OFE; SCP = Seated Chest Press; * = *p* value < .05; ** = *p* value < .01; † = *p* value < .001.

Table 5. Differentiation of peak electromyographic activity between different machines and 1RM intensities during the eccentric phase.

Eccentric phase		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	-61.09±8.07 †	146.15±19.42 †	107.99±18.17 †	153.41±20.74 †
	SCP 75%		-	207.24±22.35 †	169.08±20.31 †	214.50±23.91 †
	BIOFIT-SCP 60%			-	-38.16±7.55 †	7.26±9.42
	BIOFIT-SCP 75%				-	45.43±14.51*
	OFE-SCP					-
Clavicular pectoralis	SCP 60%	-	-59.72±5.72 †	39.68±16.51	-4.45±15.46	108.40±22.12 †
	SCP 75%		-	99.39±18.78 †	55.27±16.78*	168.12±25.04 †
	BIOFIT-SCP 60%			-	-44.12±8.30 †	68.73±11.99 †
	BIOFIT-SCP 75%				-	112.85±16.31 †
	OFE-SCP					-
LongHTB	SCP 60%	-	-60.07±6.92 †	13.90±22.49	-29.94±23.21	72.89±23.55*
	SCP 75%		-	73.97±26.27	30.13±26.70	132.96±28.10 †
	BIOFIT-SCP 60%			-	-43.84±6.50 †	58.99±10.72 †
	BIOFIT-SCP 75%				-	102.83±12.82 †
	OFE-SCP					-
LHTB	SCP 60%	-	-89.70±12.84 †	-1.71±18.26	-84.83±20.58**	115.40±20.94 †
	SCP 75%		-	87.99±23.55**	4.87±24.39	205.11±27.57 †
	BIOFIT-SCP 60%			-	-83.12±10.43 †	117.11±17.33 †
	BIOFIT-SCP 75%				-	200.23±19.84 †
	OFE-SCP					-
Anterior deltoid	SCP 60%	-	-78.08±14.19 †	2.21±24.45	-62.17±23.57	81.26±21.50**
	SCP 75%		-	80.30±25.32*	15.91±23.76	159.35±23.67 †
	BIOFIT-SCP 60%			-	-64.39±8.76 †	79.05±27.79
	BIOFIT-SCP 75%				-	143.44±30.00 †
	OFE-SCP					-

BIOFIT-SCP = BIOFIT Seated Chest Press; LHTB = Lateral head of the triceps brachii; LongHTB = Long head of the triceps brachii; OFE-SCP = Classic OFE; SCP = Seated Chest Press; * = *p* value < .05; ** = *p* value < .01; † = *p* value < .001.

Figure 4. Differentiation of maximal electromyographic activity between different machines and 1RM intensities during the complete, concentric and eccentric phases in different muscle groups.



When comparing OFE-SCP with SCP and OFE-SCP with BIOFIT-SCP, a significantly lower activation was found in OFE-SCP for all muscle groups in the full execution ($p < .001$), concentric ($p < .001$) and eccentric phases ($p < .05$), except for the SP and AD during the use of BIOFIT-SCP at 60% of 1RM ($p > .05$) during the eccentric phase. When comparing each machine (SCP and BIOFIT-SCP) with each of the two different intensities, significant differences were found in all muscle groups and during all the phases ($p < .01$).

5.22. DISCUSSION

The first objective of this research was to analyze and compare the EMG activity of the muscle groups of the upper limbs produced when exercising with the SCP, OFE-SCP, and BIOFIT-SCP machines. Based on previous studies, the performance of exercises involving internal rotation with shoulder abduction and flexion, together with elbow extension, regardless of the biomechanical differences between exercises, involve the same major muscle groups, for example, the pectoral musculature, the AD, or the triceps brachii (Cacchio et al., 2008; Stastny et al., 2017). Other studies have analyzed EMG activity in exercises such as the pec deck, chest press, or bench press, finding that they all activate the same major muscle groups, despite their technical differences, as they are all upper limb press exercises (Cacchio et al., 2008; Stastny et al., 2017; Trebs et al., 2010). Furthermore, in all the exercises performed on stable guided machines, the stabilizing musculature of the trunk may be less involved, as they rely less on the postural control, compared with exercises with more degrees of freedom of movement, as proven in previous studies that showed significant differences in rectus abdominis activation, being lower during the use of a plate machine compared with a cable-based machine (Cacchio et al., 2008). Based on this, in the present investigation, the decision was made to perform a comparison of the EMG activity with different types of machines, of the muscle groups directly involved in the movement, and not so much of the muscles that could be involved as stabilizers.

A notable finding of this research was that in all three machines, the muscle group that showed a greater RMS was the AD during the concentric phase and the LHTB during the eccentric phase in general. These results coincide with those found in similar works, with the AD being the upper limb muscle that showed the

greatest activation during the use of the standing cable press (Signorile et al., 2017). As for the activation of the LHTB, it could be due to the need for stabilization of the movement, as proven in previous works in which stronger signals were recorded in exercises with a freer movement with respect to chest press machines for this muscle group (Cacchio et al., 2008).

An outstanding result of the present investigation was that when comparing EMG activity between machines with the same percentage of intensity, more specifically, SCP and the BIOFIT-SCP, the SP presented a significantly greater EMG signal in all phases recorded in the SCP with respect to the BIOFIT-SCP at the same relative intensities; while the CP showed greater activation in the SCP with respect to the BIOFIT-SCP, but only in the eccentric phase at 75% of the 1RM. This may be due to the fact that the bundles of the SP and CP parts have a recruiting advantage during horizontal glenohumeral flexion and may be due to the better alignment of the muscle fibers with respect to the direction of movement (Albarello et al., 2022; Trebs et al., 2010) during the execution of the SCP, but that the fibers did not maintain the same linearity during the execution of the BIOFIT-SCP. Furthermore, in previous studies where a comparison of the EMG activity of each muscle between exercises and grips was performed, it was observed that a bench press with a grip at 50% of the biacromial distance compared with a grip of 150% of the biacromial distance, presented a lower activation of the SP (Muyor et al., 2023). Thus, the fibers of the CP and SP were able to collaborate to a greater extent in all phases in the SCP machine with respect to the BIOFIT-SCP machine due to the closest grip in the exercise performed on traditional machines (Albarello et al., 2022). Given these preliminary results, questions remain as to the importance of fixed or adaptive grip distance during the use of this type of machinery on EMG activation in upper limb pushing exercises.

Continuing with the comparison between the SCP and the BIOFIT-SCP, in the case of the elbow extensors, the LongHTB showed no differences between machines at equal intensity, while the LHTB showed greater activation in the BIOFIT-SCP in the full and concentric phases, both at 60% and 75%, with no differences in the eccentric phase. Studies have justified the participation of the triceps as a synergist muscle in upper limb pushing exercises (Cacchio et al., 2008) and thrust exercises that increased its activation by elevating the firing frequency through the inclusion of a backrest that improved the intervention of the main

musculature because it reduced the dependence of the stabilizing muscle during the exercise (Signorile et al., 2017). However, in most studies, the triceps brachii was analyzed uniquely as a muscle group, but locating the electrodes in only one of the muscle bellies (Cacchio et al., 2008; Coratella et al., 2019; Muyor et al., 2023; Signorile et al., 2017), with this being the first article to analyze on different machines, the activation of two triceps muscle bellies, the LHTB and the LongHTB. The differences found between both machines in the EMG activity of the triceps brachii musculature may be conditioned by the angulation of the shoulder joint because the BIOFIT-SCP involves a shoulder flexion to a greater extent, while the SCP an adduction flexion, which would condition the EMG involvement of the triceps based on previous studies (Trebs et al., 2010). Given these promising results, future research is needed to analyze the biomechanics of both machines in order to confirm the results of the present investigation.

Similarly, when comparing EMG activation between SCP and BIOFIT-SCP, the AD showed greater activation in the BIOFIT-SCP in the full and concentric phases, both at 60% and 75%, with no differences in the eccentric phase. This could also be a consequence of the differences in shoulder abduction between the two machines. It has been shown that the AD is involved, to a greater extent, in exercises where the main movement consists of shoulder flexion, compared with those where the main movement is horizontal shoulder adduction (Trebs et al., 2010). In that sense, the movement in the BIOFIT-SCP is based on a shoulder flexion and an elbow extension with a small shoulder internal rotation, while the movement in the SCP involves a shoulder internal rotation and elbow extension, together with a steady shoulder abduction. Previous results on this issue are contradictory. Thus, while in some studies, it has been found that when comparing different types of plate-loaded chest press and cable-based strength training machines, the AD did not show significant differences between machines (Signorile et al., 2017). In other studies, it was found that the AD increased its activation during a chest press exercise as the inclination of the bench changed, leading to an increase in shoulder flexion (Trebs et al., 2010). The differences between studies may be due to the dependence of the execution technique in each of the variants of the exercises because the contribution of a specific muscle will depend on factors such as the specific movement performed in the joint and the anatomical position of the muscle

(Trebs et al., 2010). These promising results indicate the need for future research to analyze the biomechanics of both machines to validate the findings of this study.

Another relevant result of this study was that, when comparing the EMG activity of the BIOFIT-SCP and SCP machines to the OFE-SCP, those machines equipped with an external weight selector showed significantly higher EMG values across all muscle groups, irrespective of the intensity and phase, with only a few exceptions. However, OFE has gained significant popularity in recent years (Chow et al., 2021; Chow & Wu, 2019; Liu et al., 2020). No prior studies have been identified that have examined EMG activity using this type of machine, leaving its effectiveness uncertain (Mehr, 2013). However, prior research has indicated that the choice of intensity influences muscle fiber recruitment, thereby affecting the recorded signal (Cormie et al., 2011). Given that the traditional OFE line only permits exercises using one's own body weight (Liu et al., 2020), the results of this study may be attributed to the fact that the participants' body weight did not correspond to an intensity near 60% or 75% of their 1RM when using the OFE-SCP. Thus, based on the results of this study, OFE-SCP may have limited effectiveness in generating significant EMG activity (Mehr, 2013). Thus, based on the findings of this study, OFE-SCP may have limited effectiveness in generating significant EMG activity (Schwanbeck et al., 2020), being able to provide only an adequate stimulus in populations with low fitness levels, such as older, deconditioned individuals (Kim et al., 2018).

Based on the results found in the present investigation, the first hypothesis of this research can be partially accepted, as we found higher EMG activation in SCP and BIOFIT-SCP, as compared to OFE-SCP. However, the second part of the hypothesis, which hypothesized that the EMG activation between the machines with a load selector would be similar (SCP vs. BIOFIT-SCP), has to be rejected, as differences were found in four of the five muscle groups analyzed.

The second aim of this study was to assess the differences in EMG activity of upper limb muscle groups at 60% and 75% of the 1RM using machines that permit intensity adjustment (SCP and BIOFIT-SCP). The results indicated a rise in EMG activity across all the muscle groups analyzed when exercising at 75% of the 1RM compared to 60% of the 1RM for both the full range of motion as well as during the concentric and eccentric phases in the SCP and BIOFIT-SCP. The results are consistent with previous studies, which also reported an increase in EMG activity

as intensity increased (Snyder & Fry, 2012). This occurs because, at higher intensities, there is an increase in both the recruitment of motor units and their firing frequency (Cormie et al., 2011). These results support the acceptance of the second hypothesis, as the EMG activity recorded at 75% of 1RM was higher than at 60% of 1RM in both SCP and BIOFIT-SCP conditions.

The primary practical implication of this research is the introduction of a new type of OFE, accessible to both trainers and users, supported by scientific evidence demonstrating its effectiveness in recruiting target muscles similarly to conventional gym equipment. Furthermore, the effectiveness of the OFE was enhanced by implementing an external load selection system. This approach not only ensured adherence to the principle of progressive intensity but also improved the control of training intensity when using these machines.

The main strength of the present research is that it is one of the first studies that has analyzed EMG activity in OFE with a load selector. As studies were not found that compared similar models of indoor and outdoor machines for upper limb exercises, the present study is a pioneer in this aspect. It is also one of the first articles that has analyzed the EMG activation generated by classic OFE, which works with the user's own weight and whose shortcomings have been widely discussed. In addition, this work opens up new avenues of research by suggesting biomechanical and electromyographic analyses of the new patented systems and validities, offering opportunities to optimize their design and functionality in various contexts. In addition, it is one of the few works that includes both the eccentric and concentric phases, as well as the separate analysis of the sternal and clavicular parts of the pectoralis major muscle. In addition to the above, it is the only study that analyzed two of the triceps muscle bellies in guided machines.

Although this study offers a novel approach compared to prior research on the effectiveness of OFE, it is not free from limitations. Firstly, this study did not include an analysis of EMG results for antagonist muscles like the biceps brachii, latissimus dorsi, or other areas such as the lateral deltoid. The location of the electrodes in the back area makes measurement difficult because of the backrest of the machines. On the other hand, future work is encouraged to include an analysis of a larger number of muscle groups whenever possible. A second limitation was that the three machines presented slight variations in execution biomechanics due to the specific mechanics of each device, making direct comparisons between the

exercises imprecise. However, it is important to note that studies with an electromyographic component often aim to highlight these biomechanical variations, providing valuable information on how different equipment or variations within the same exercise uniquely affect muscle activation. These comparisons are essential to understanding the nuances of muscle responses. The third limitation of this study was the exclusion of the maximum voluntary contraction test as a variable in the EMG analysis. This work compared the machines using the absolute values recorded. Including this variable could have provided insights into the percentage of activation of each muscle group relative to its maximum during each of the exercises assessed. In addition, it was not possible to calculate the 1RM in the OFE-SCP due to the impossibility of adjusting the load on the machine when working with one's own body weight and mobilizing it with levers. As a final limitation, although the study incorporated an electrogoniometer for elbow joint monitoring during electromyographic signal recording, it did not incorporate a goniometric analysis of the elbow and shoulder joints, which might have provided information on joint angles and their relationship to muscle activation patterns. In addition, it could have provided findings by linking specific joint mechanics to differences in muscle recruitment across machines, such as the difference in angular velocity between shoulder and elbow and whether this changes the data recorded in the interfering muscle groups.

5.23. CONCLUSIONS

It was observed that the EMG activity presented by the current OFE designed to strengthen the upper limb musculature (OFE-SCP) is significantly lower than that of the SCP, a machine commonly used in strength training in fitness centers for the pectoralis, with higher activation in triceps. In contrast, classic OFE, which only allows self-loading work, was found to be less effective than seated chest press machines with external load selectors. Machines with external weight selectors (SCP and BIOFIT-SCP) consistently showed higher EMG activations across all muscle groups compared with self-loading OFE, suggesting that these may be less effective in generating sufficient muscle activation for hypertrophy and strength adaptations, except for populations with lower fitness levels. Thus, the study supports the idea that OFE with external load selectors represent a valuable tool for strength training, as they show EMG activity levels closer to those of

conventional gym equipment. This innovation could improve the applicability of OFE in progressive training programs by allowing controlled intensity adjustments. Additionally, in general terms, a higher intensity implied a greater activation of the involved musculature. This study is a pioneer in the analysis of EMG activation in OFE with external load selection, as it included a separate analysis of the pectoralis major parts and two triceps muscle heads. Future studies should address the limitations of this research, proposing as future lines of research the inclusion of the analysis of antagonist muscles, the goniometric analysis of elbow and shoulder joint angles, as well as taking into account the differentiation of biomechanics of execution between machines, and the maximal voluntary contraction test, in order to know what percentage of activation is generated in each muscle group and to refine the understanding of muscle activation patterns. In addition, it will be necessary to expand the sample to be analyzed, taking into account the female population as well as the older population in future research in order to achieve a greater transfer to the population.

In summary, OFE equipped with external load selectors has the potential to bridge the gap between traditional self-weight OFE and gym-based strength training equipment, offering a controlled approach to muscle activation and adaptation for outdoor fitness applications.

5.24. PATENTS

This study presents data on two patents registered by the Spanish Patent and Trademark Office: a new machine designed for the outdoor fitness equipment line (code: ES2975897) and an innovative external load selection system of the exercise for this machine (code: ES2975886).

**ESTUDIO 5: COMPARATIVE
ELECTROMYOGRAPHIC ANALYSIS IN
LEG PRESS OF TRADITIONAL FITNESS
EQUIPMENT, TRADITIONAL OUTDOOR
FITNESS EQUIPMENT, AND A NEW
MODEL OF OUTDOOR FITNESS
EQUIPMENT IN TRAINED YOUNG MEN**

Vb – ESTUDIO 5: Comparative Electromyographic Analysis in Leg Press of Traditional Fitness Equipment, Traditional Outdoor Fitness Equipment, and a New Model of Outdoor Fitness Equipment in Trained Young Men

5.25. ABSTRACT

This study compares the electromyographic activity (EMG) of different muscle groups (rectus femoris, vastus lateralis, biceps femoris, tibialis anterior, and gastrocnemius) of the lower limbs when performing a traditional seated leg press (SLP) with a classic piece of outdoor fitness equipment (OFE-SLP), and with a new OFE leg press that allows the user to adjust the intensity of the exercise by means of a selectorized system (BIOFIT-LP). It was found that the EMG of the OFE-SLP was significantly lower than that of the SLP, but similar activations to those of the SLP were achieved with the BIOFIT-LP. In conclusion, the inclusion of a system to be able to change intensity of the exercise in OFE achieves an EMG activity similar to traditional machinery in trained young men.

5.26. INTRODUCTION

The practice of strength training has become popular in recent years, due to the various benefits it brings to the health and functionality of its practitioners (Armstrong et al., 2022; Fragala et al., 2019; Martín-Fuentes et al., 2020a). Increased strength, hypertrophy, and metabolic improvements are some of the results sought through this type of training (Armstrong et al., 2022; Escamilla et al., 2001). To carry this out, multiple resources can be employed, with the use of conventional gym equipment for strength training being one of the most common methods (Escamilla et al., 2001; Sarto et al., 2020; Schwanbeck et al., 2020). In addition, in recent years, a new line of outdoor fitness equipment (OFE) has emerged, which is sports equipment similar in operation to traditional gym equipment, but commonly located in outdoor public spaces such as parks (Abelleira-Lamela et al., 2021; Chow & Wu, 2019). It has become easier to find OFE due to its increasing popularity,

especially among adults and older people who want to improve their health through outdoor strength training (Chow & Wu, 2019; Marcos-Pardo et al., 2024).

It is known that lower limb muscle mass and strength is a determining factor for multiple aspects such as functional capacity (Handsfield et al., 2014) and sports performance (Da Silva et al., 2008), with strength training of this part of the body being the quintessential means of skeletal muscle mass gain (van den Tillaar et al., 2021). This has led to a proliferation of machinery to exercise the lower limb musculature, most of them being multi-joint (Alizadeh et al., 2020; Da Silva et al., 2008; van den Tillaar et al., 2019) and involving different muscle groups (E. M. Da Silva et al., 2008).

However, prior to the use of any type of machinery for strength work, it is necessary to analyze whether it is effective, i.e., whether it achieves a sufficient activation to generate adaptations of the musculature involved, and whether it is safe, i.e., whether it is not harmful to the musculoskeletal and joint health of the exercise performer (Miyajima et al., 2010). In terms of efficacy, techniques such as surface electromyographic analysis (sEMG) are used to determine the musculature involved in the exercise action. This tool allows the study of muscle function through electrophysiological recording techniques that detect the electrical potentials that cross the membrane of the fibers in the superficial muscles involved in each exercise (Krause Neto et al., 2019). In this way, electromyographic activity (EMG) makes it possible to discover the degree of neuromuscular activation during the execution of an exercise for each of the muscle groups that are analyzed, demonstrating its efficacy (Llurda-Almuzara et al., 2021; Zambrano et al., 2023).

Many studies have analyzed the EMG of the different muscle groups of the lower limbs in exercises performed with conventional gym equipment (Martín-Fuentes et al., 2020b; Trebs et al., 2010), finding that guided machines such as the traditional seated leg press (SLP) are effective for the work of this muscle group, with activation especially observed in the quadriceps femoris muscles (Lee et al., 2017). In this type of equipment, it has also been shown that submitting the subject to a greater intensity generates a greater EMG of the involved muscles (Gonzalez et al., 2017). However, despite the popularity of OFE and, in many cases, the large investment of public funds being made for the purchase and installation of these machines in public spaces (Chow & Wu, 2019; Kim et al., 2018), thus far it has only been found that their use can improve both the body composition and strength

production capacity in legs and arms in the older population (Marcos-Pardo et al., 2024), and no studies have analyzed whether OFE is effective, i.e., whether it involves the target musculature at an intensity sufficient to generate structural adaptations in the muscle. On the other hand, classical OFE does not allow progression of the intensity of the exercise, as it allows work exclusively with a self-body mass as the unique intensity of the exercise (Liu et al., 2020). Therefore, it would be interesting to also analyze the EMG with a new line of OFE that does allow an increase in intensity of the exercise, with a system similar to that of traditional gym equipment. However, so far there are no data available in this regard either.

Therefore, the objectives of this research were: (a) to analyze and compare the EMG of the lower limb muscle groups when performing an SLP with traditional gym equipment, a leg press machine of classic OFE (OFE-SLP), and a leg press machine belonging to a new line of OFE which allows an adjustment in the intensity of the exercise by means of a selectorized system (BIOFIT-LP); and (b) to determine the differences in the EMG of the lower limb muscle groups at 60 and 75% of the 1RM in the machines that allow the selection of the intensity of the exercise (SLP and BIOFIT-LP).

Regarding the hypotheses of the present investigation, it is hypothesized that: (a) there will be an EMG activation of the lower limb muscles when performing the SLP in the three machines, with the activation being greater when using the machines that allow increasing the intensity of the exercise (SLP and BIOFIT-LP) than in those that only allow working with a self-body weight as the unique intensity of the exercise (OFE-SLP). This could imply that the SLP and BIOFIT-LP machines are more effective for lower limb strength training than the OFE-SLP machine. It is also hypothesized that the activation will be similar between the machines that allow selecting the intensity of the exercise (SLP vs. BIOFIT-LP) for the major muscle groups involved, with differences in some of the synergists. This would imply that both could be equally effective in working on lower limb strength in general, with the differences in EMG activation found between both machines being due to biomechanical differences in their execution. Because of the above, the machinery to work with could be selected according to the synergists one prefers to involve to a greater extent; and (b) the greater the intensity of the exercise on the machine, the greater the EMG of the muscles involved in both machines. The

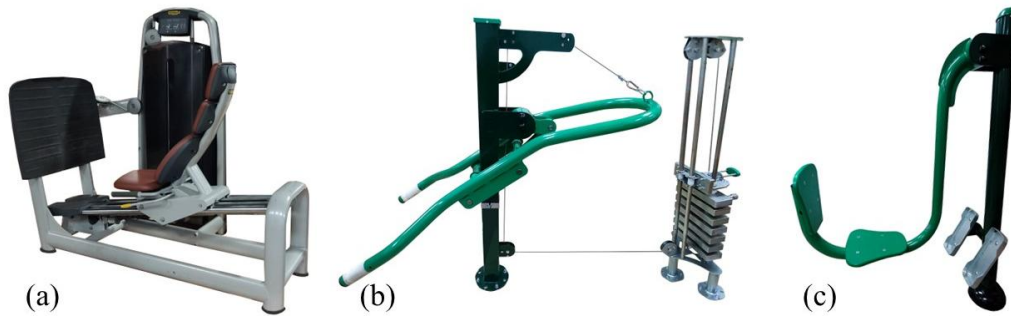
consequence of this hypothesis, if it is proven, would be that the intensity of the exercise can be used as another variable in the estimation of the training load, regardless of the model, in the machines that allow a selection of the load.

5.27. MATERIALS AND METHODS

5.27.1. Experimental Approach to the Problem

A randomized cross-sectional study was carried out. It consisted of a cross-sectional study where the 1RM was calculated on the seated leg press (SLP) (Figure 1a) and the new BIOFIT leg press (BIOFIT-LP) (Figure 1b) (session 1 and session 2, 72 h apart), and the EMG activity of five muscle groups was analyzed on three different types of leg press machines (session 3, 72 h after session 2). With respect to the machines chosen, one belongs to a line commonly used in the fitness field, more specifically the SLP model (Technogym; Cesena, Italy), which allows adjusting the intensity of the exercise through the use of a selectorized system (Escamilla et al., 2001) (Figure 1a); another is from a classic OFE machine line, corresponding with the same machine model, the Columpio (OFE-SLP) (Entorno Urbano, Murcia, Spain) (Figure 1c), which only allows exercising with self-weight as the unique intensity of the exercise (Chow et al., 2021); and a third one belongs to a new line of OFE, corresponding to the same machine model, called BIOFIT-LP (Entorno Urbano, Murcia, Spain), which allows adjustment of the intensity of the exercise by means of a selectorized system (Escamilla et al., 2001), and which is currently under patent registration (patent registration for the OFE-SLP at the Spanish Patent and Trademark Office, application number: ES2975897; and patent registration for the selector of the intensity of the exercise, Spanish Patent and Trademark Office, application number: ES2975886) (Figure 1b). The operation of this machine is based on two handles to be taken on both sides of the body, starting the movement from a 90° flexion of the knee, and from here one must complete a full knee extension against resistance and against gravity (concentric phase). The intensity of the exercise is selected with a selectorized system. On the other hand, the eccentric phase of this exercise goes from knee extension to 90° knee flexion, a descent movement that is done in favor of gravity (eccentric phase). The study utilized a specific research model, as illustrated in Supplementary Table S1.

Figure 1. Fitness equipment used. (a) Seated leg press (Technogym; Cesena, Italia); (b) outdoor fitness equipment leg press with selectorized system (Entorno Urbano, Murcia, Spain); (c) outdoor fitness equipment seated leg press (Entorno Urbano, Murcia, Spain).



The study was designed according to the principles of the Declaration of Helsinki and with the prior approval of the institutional ethics committee of the Universidad Católica de Murcia (Ethical Application Ref: CE111908). All participants were informed of the tests to be performed and voluntarily signed a consent form prior to the start of the study.

5.27.2. Subjects

To calculate the sample size, we used the methodology from previous studies based on the standard deviation (SD) (Bhalerao & Kadam, 2010). The Rstudio 3.15.0 software was used for this purpose. Sample size and power were established according to the standard deviation of the peak EMG activity of the biceps femoris variable ($SD = 49.68 \mu V$) presented by a sample of similar characteristics, composed of young males ($n = 10$) (Schoenfeld et al., 2014). With an estimated error (d) of $30.79 \mu V$, a confidence interval of 95% (95% CI), a power of 95%, and a significance level of 0.05, the minimum sample needed for conducting the study was 34 subjects.

The sample consisted of 34 males (mean age = 21.54 ± 1.80 years; mean body mass = 74.27 ± 9.99 kg; mean height = 176.62 ± 6.67 cm). The inclusion criteria were: (1) having at least 2 years of experience in training with gym machines and currently training with this methodology at least three times a week; (2) being between 19 and 24 years old; and (3) being male. The exclusion criteria were: (1) having exercised in the 48 h prior to the first session or between evaluation sessions

(Trebs et al., 2010); (2) having suffered any lower extremity, hip, or back injury in the last 6 months; and (3) having any known muscle abnormality or joint disease.

5.27.3. Measurements

5.27.3.1. Questionnaire

All participants completed an ad hoc questionnaire to obtain their sociodemographic characteristics, as well as their experience in sports and in the field of machine training and the injuries and pathologies suffered.

5.27.3.2. Anthropometric Characteristics

Anthropometric measurements of body mass and height were taken following the indications of the International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al., 2019) by an ISAK-accredited level 2 anthropometrist. A Tanita BC-545N scale (Tanita, Arlington Heights, IL, USA) and an HR001 portable stadiometer (Tanita, Arlington Heights, IL, USA) were used.

5.27.3.3. Determination of 1RM

The calculation of the 1RM was performed on the SLP and BIOFIT-LP machine, both of which have a selectorized system that allows the intensity of the exercise to be modified. This test was not performed with the OFE-SLP as it does not have any system for increasing the external intensity of the exercise. For the 1RM tests, the order of execution of the SLP and BIOFIT-LP was randomized. In both cases, the protocol proposed by the National Strength and Conditioning Association (Miller, 2012) was employed. Volunteers warmed up by performing a set with an intensity of the exercise with which they could perform between 5 and 10 repetitions. After 1 min of rest, the intensity of the exercise was increased by 10 to 20%, an intensity of the exercise with which the participant had to perform a minimum of 3 and a maximum of 5 repetitions. After 2 min of rest, the intensity of the exercise was increased once again by 10 to 20%. With this intensity of the exercise, the participant had to perform a minimum of 2 and a maximum of 3 repetitions. After this, the intensity of the exercise was increased again by 10 to 20% to perform one repetition, with this weight increased or reduced by 5 and 10%, depending on whether it was lifted correctly or not, until the intensity of the

exercise corresponding to the 1RM was obtained. This required a maximum of 5 attempts with different intensity of the exercises, with 4 min of rest between each of them (Miller, 2012). After 72 h, the same protocol was performed on the other machine, according to the previous randomization performed.

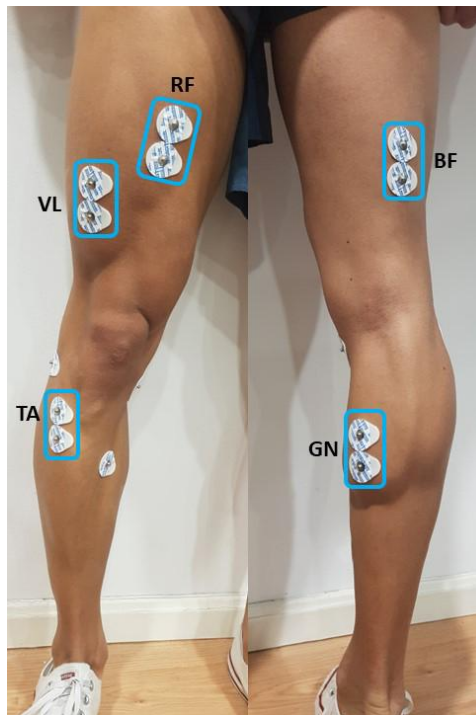
5.27.3.4. *Electromyographic (EMG) Analysis*

In a third measurement session, separated by 72 h from the previous session, the EMG of the quadriceps femoris (rectus femoris and vastus lateralis), biceps femoris (long head), tibialis anterior, and gastrocnemius (medial head) muscle groups was measured when performing 5 repetitions on the SLP and BIOFIT-LP machines at 60 and 75% of 1RM. These intensities were chosen as they are commonly used in different training programs, as well as in different EMG studies with guided machinery (López-Vivancos et al., 2023). The OFE-SLP EMG was analyzed with a single intensity of the exercise allowed (self-weight).

For electrode placement, the different skin areas where the electrodes would be placed were prepared by shaving the hair and cleaning the skin with 96% alcohol and sterile gauze to reduce skin impedance (Da Silva et al., 2008; Zambrano et al., 2023). Gelled disposable surface electrodes were used, placed with a 2 cm center-to-center distance, aligned with the longitudinal axis of the muscle fibers, following the methodology from previous studies (Stegeman & Hermens, 2007). The electrodes were placed according to the recommendations of the Surface Electromyography for the Non-invasive Assessment of Muscles (SENIAM) (Stegeman & Hermens, 2007) for each of the muscles measured: quadriceps femoris (rectus femoris and vastus lateralis), biceps femoris (long head), tibialis anterior, and gastrocnemius (medial head) (Figure 2). Consistent with similar research, bilateral symmetry was assumed during exercise performance, so electrode placement on the right side of the body was standardized (Snarr & Esco, 2013). EMG activity during the exercises was recorded using a surface electromyography system at a sampling rate of 1500 Hz (MuscleLab Ergotest Innovation AS, Stathelle, Norway). The electromyographic signal during the calculation of the 1RM was not taken, since the variability that the EMG signal would present due to fatigue because of the procedure used following the indications of the National Strength and Conditioning Association could lead to bias. In addition, as the sessions in which 1RM was calculated and the sessions in which EMG data were collected

were different, variables such as skin impedance or hydration could include more intra-subject variability (Da Silva et al., 2008; Zambrano et al., 2023). Therefore, it was decided to measure EMG activation only on the third day, which was the day on which the performance on the different machines was compared.

Figure 2. Electrode location on the right leg (left—anterior view; right—posterior view). RF—rectus femoris, VL—vastus lateralis, BF—biceps femoris, TA—tibialis anterior, GN—gastrocnemius.



Prior to the study, intra-instrument reliability was assessed with a group of 10 training young men by means of test–retest. The tests described above were performed two times in the same session on the same volunteers (Carius et al., 2015). It was determined that the electromyographic analysis used in the present study was highly reproducible with a coefficient of variation between 7 and 14% for all muscles on all machines, confirming that the measurement used was sufficiently reproducible.

5.27.3.5. *Determination of Concentric and Eccentric Phases*

To differentiate the concentric and eccentric phases during exercise execution, a MuscleLab twin axial electrogoniometer was used (Ergotest

Innovation AS, Stathelle, Norway). It was placed on the subject's left leg at the knee joint on the lateral outer side. The distal gauge of the goniometer was aligned with respect to the leg, while the fixed gauge was aligned with respect to the thigh (Mitchell et al., 2017). It was calibrated using a hand-held goniometer at 90° of knee flexion in stable relaxed sedentation. The point of maximum knee extension was checked in situ, thus differentiating the concentric phase as those data recorded from the beginning at 90° of knee flexion up to that maximum knee extension, and the eccentric phase as the data recorded from maximum knee extension to 90° of knee flexion. The complete phase consisted of the analysis of the entire joint range recorded from 90° of onset to 90° of end (Rossi et al., 2018).

5.27.4. Randomization and Blinding

Following the methodology from previous studies, the order of execution of the machines for 1RM analysis, of execution of the machines for EMG analysis, and of the 1RM intensity at which each machine was to be started were randomized (Schoenfeld et al., 2014). This process was performed by the principal investigator in the presence of investigators external to the present research, using a computer-generated random number table.

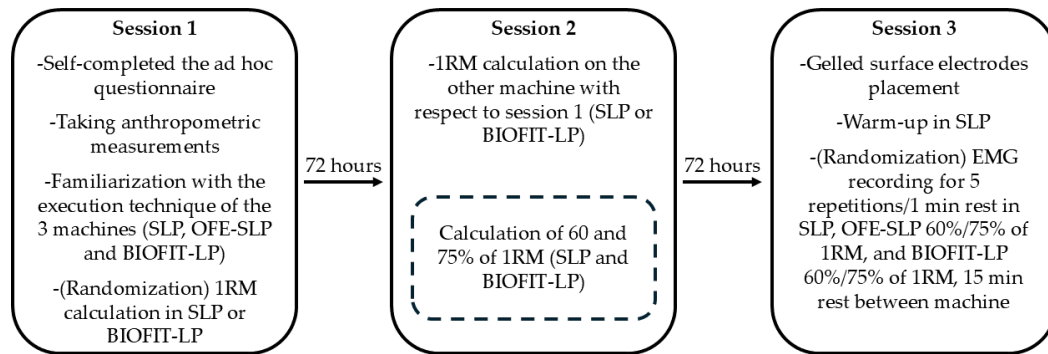
All measurements were performed after randomization. The investigators who performed the EMGs did not participate in the 1RM calculation tests. In the measurements, the two investigators involved in the data collection were also cross-blinded, whereby one controlled the exercise execution technique and provided the guidelines for the development of the protocol, and the other investigator was only in charge of verifying the correct recording of the EMG data.

5.27.5. Procedure

Figure 3 shows in schematic form the procedures carried out during the three sessions. In session 1, the volunteers self-completed the ad hoc questionnaire, followed by anthropometric measurements. After this, the key points for the correct execution on each of the three machines (SLP, OFE-SLP, and BIOFIT-LP) were explained to them, in order to familiarize the participants with the expected execution technique on each of them for data collection. More specifically, an indication was given to them that the executions on the different machines should

include the full range of motion from a 90° knee flexion to full extension, keeping the sole of the foot fixed in position and maintaining contact with the floor/platform for the duration of the repetition.

Figure 3. Flow diagram.



After this, the subjects performed the procedure for the calculation of the 1RM on the SLP or BIOFIT-LP machines, whose execution order was established randomly. In session 2, the process was repeated for the other machine. With the data obtained with this procedure, the 60 and 75% values of the 1RM intensity of the exercise were subsequently calculated for each subject on both machines.

In session 3, after electrode placement, participants performed a warm-up set consisting of 12 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 8 repetitions at 70% of 1RM, and 2 repetitions at 90% of 1 RM on the SLP machine, as the subjects had the most previous experience with it, as in similar studies (Andersen et al., 2018). Subsequently, the EMG measurement was started in the machine assigned randomly (SLP, OFE-SLP, or BIOFIT-LP). In the case of SLP and BIOFIT-LP machines, the intensity was also randomized (60% or 75% of 1RM). The participant was asked to perform 5 repetitions on the first machine and at the first intensity percentage, with a constant speed throughout (E. M. Da Silva et al., 2008). A rest of 1 min was given between each of the repetitions to avoid the effect of fatigue. After 15 min, the same protocol was performed on the same machine, but with the other intensity percentage. After finishing the entire protocol with the first machine, a 15 min rest was provided, after which the protocol was started with the second machine, following the same procedure described above (Da Silva et al., 2008). In the OFE-SLP case, 1 set of 5 repetitions was performed following the procedure previously described with the participant's self-weight, as the

participant's intensity of the exercise could not be adjusted (Chow et al., 2021). Resting times were set following previous methodologies, so that fatigue would not affect the results (Gonzalez et al., 2017). For the analysis of the data, the methodology of a previous study was followed (Da Silva et al., 2008); the first and last repetitions were discarded, and the repetition with the highest root mean square (RMS) of the main muscle group of the movement, the rectus femoris, was selected, provided that it had been performed correctly, with a recording performed in each of the muscles involved (Padulo et al., 2013; Picerno et al., 2016; van den Tillaar et al., 2019).

All measurement sessions were separated by 72 h to avoid possible fatigue effects (Picerno et al., 2016). All subjects were summoned to all sessions at 8:00 a.m. The measurements were performed in the same room, with a standardized temperature of 20 °C and constant humidity conditions (60%).

5.27.6. Statistical Analysis

All data were analyzed using the Muscledlab v10.5.67 software (MuscleLab Ergotest Innovation AS, Stathelle, Norway) by passing the raw amplified EMG signal to RMS (Padulo et al., 2013; van den Tillaar et al., 2019). Thus, the RMS of the peak EMG activity variable was taken in the complete repetition, and in its concentric and eccentric phases, for each muscle group, for the subsequent comparison between machines, as in previous studies (Albarelo et al., 2022). The statistical analysis of the data was performed using SPSS software (Version 25; IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test and Mauchly's W test were used to evaluate the normality of the data. The mean and standard deviation were calculated. A repeated-measures ANOVA and Bonferroni's correction were used to compare the different muscle activations between machines. To protect against a Type I error, Bonferroni's correction was used to achieve $p = .005$ for statistical significance. The effect size was calculated using partial eta-squared (η^2p) for analysis of variance and will be defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: $ES \geq 1.2$; or very large: $ES \geq 2.0$. An error of $p < .05$ was established.

5.28. RESULTS

Table 1 shows the 1RM strength test results for the traditional SLP and BIOFIT-LP machines.

Table 1. Results of the 1RM strength test.

	1RM	60% 1RM	75% 1RM
SLP (kg)	201.51±35.35	120.91±21.21	151.14±26.51
BIOFIT-LP (kg)	56.31±13.72	31.85±11.27	39.82±14.09

1RM = one-repetition maximum; BIOFIT-LP = BIOFIT leg press; SLP = traditional seated leg press.

Table 2 and Figure 4 show the mean and standard deviation of the root mean square recorded in each of the muscles analyzed during the use of the SLP at 60 and 75% of 1RM, the BIOFIT-LP at 60 and 75% of 1RM, and the OFE-SLP with self-weight as intensity of the exercise. In all cases, it was found that the vastus lateralis was the muscle group that attained the greatest activation, followed by the rectus femoris, and thirdly by the tibialis anterior. After these, in the case of SLP and BIOFIT-LP, the next muscle groups with the highest activation were the biceps femoris and gastrocnemius, in that order; while with the OFE-SLP machine, the order of the latter was reversed.

Table 2. Root mean square (μ V) recording of the electromyographic signal in the different machines with different 1RM intensities.

	VL (M±SD)	RF (M±SD)	BF (M±SD)	TA (M±SD)	GN (M±SD)
Complete					
SLP 60%	199.17±61.46	134.96±50.57	64.77±38.23	68.29±37.92	61.43±32.66
SLP 75%	241.01±70.83	176.98±72.18	82.17±39.51	88.08±37.27	77.65±37.31
BIOFIT-LP 60%	219.09±69.23	149.25±64.14	57.51±33.48	133.69±63.86	39.48±20.78
BIOFIT-LP 75%	235.99±75.52	162.60±67.85	67.91±36.25	140.83±80.50	43.11±19.41
OFE-SLP	66.89±26.28	30.00±17.76	21.22±10.04	58.18±55.18	40.18±26.93
Concentric					
SLP 60%	224.98±66.44	149.84±60.63	77.11±38.01	81.63±46.72	75.83±41.86
SLP 75%	274.71±80.92	206.55±88.28	95.83±43.83	100.44±49.77	90.85±40.21
BIOFIT-LP 60%	251.12±80.71	157.21±74.59	69.14±30.52	104.11±51.47	48.86±26.96
BIOFIT-LP 75%	271.15±91.27	175.80±74.10	82.08±38.36	120.86±67.79	50.45±22.55
OFE-SLP	75.26±32.99	28.09±13.92	25.92±12.39	38.52±31.77	49.11±32.26
Eccentric					
SLP 60%	168.86±66.04	114.56±56.17	39.28±26.53	49.32±31.60	41.51±23.71
SLP 75%	196.34±70.17	138.85±60.05	50.26±27.46	68.47±30.36	53.89±27.49

BIOFIT-LP 60%	179.06±59.44	138.64±63.56	26.94±11.79	151.36±89.07	24.41±13.89
BIOFIT-LP 75%	187.59±60.51	146.03±68.19	32.87±15.79	153.58±104.76	30.84±18.44
OFE-SLP	57.08±27.61	28.70±19.35	16.00±9.36	64.52±70.84	30.65±23.68

BF = Biceps Femoris; BIOFIT-LP = BIOFIT Leg Press; GN = Gastrocnemius; OFE-SLP = Classic OFE; RF = Rectus Femoris; SLP = traditional Seated Leg Press; TA = Tibialis Anterior; VL = Vastus Lateralis.

Figure 4. Root mean square (μV) representation of the electromyographic signal in the different machines with different 1RM intensities.

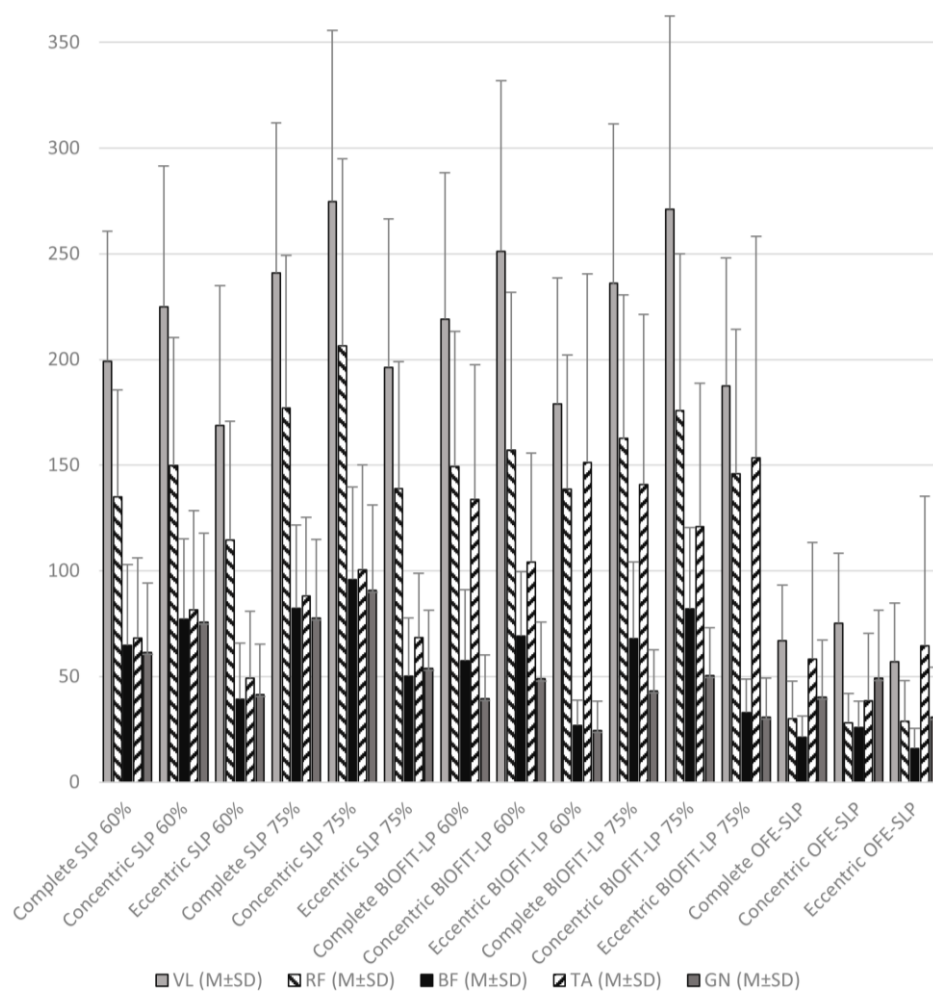


Table 3 shows the differences between machines and between intensity percentages in the complete run, Table 4 shows the concentric phase, and Table 5 shows the eccentric phase. No significant differences were found in the activation of any muscle group when comparing the SLP and BIOFIT-LP machines at the

same intensity (60% 1RM vs. 60% 1RM or 75% 1RM vs. 75% 1RM), neither in the complete run, in the concentric phase, nor in the eccentric phase ($p > .05$), except for the biceps femoris in the eccentric phase at 75% 1RM, which showed a greater significant activation in SLP as compared to BIOFIT-LP (ES = 0.60; moderate effect size; $p < .01$); in the tibialis anterior, where there was a greater activation at both intensities in the BIOFIT-LP machine in the full stroke (ES = 0.53–0.86; moderate effect size; $p < .01$ –.001) and eccentric phase (ES = 0.69–0.89; moderate effect size; $p < .001$), but not in the concentric phase (ES = 0.3–0.5; moderate effect size; $p > .05$); and gastrocnemius, which showed a greater activation in SLP than in BIOFIT-LP at both intensities and all phases (ES = 0.68–0.91; moderate effect size; $p < .05$ –.001).

Table 3. Differentiation of peak electromyographic activity (μV) between different machines and intensities of 1RM during a full execution.

Complete repetition		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	-41.84 $\pm$ 4.48 [†]	-19.92 $\pm$ 8.38	-36.82 $\pm$ 9.80**	132.285 $\pm$ 8.82 [†]
	SLP 75%	41.84 $\pm$ 4.48 [†]	-	21.91 $\pm$ 8.16	5.01 $\pm$ 9.93	174.12 $\pm$ 10.91 [†]
	BIOFIT-LP 60%	19.92 $\pm$ 8.38	-21.91 $\pm$ 8.16	-	-16.90 $\pm$ 5.03*	152.21 $\pm$ 9.76 [†]
	BIOFIT-LP 75%	36.82 $\pm$ 9.80**	-5.01 $\pm$ 9.93	16.90 $\pm$ 5.03*	-	169.11 $\pm$ 10.82 [†]
	OFE-SLP	-132.29 $\pm$ 8.82 [†]	-174.12 $\pm$ 10.91 [†]	-152.21 $\pm$ 9.76 [†]	-169.11 $\pm$ 10.82 [†]	-
Rectus Femoris	SLP 60%	-	-42.02 $\pm$ 5.84 [†]	-14.30 $\pm$ 8.89	-27.64 $\pm$ 10.59	104.96 $\pm$ 8.03 [†]
	SLP 75%	42.02 $\pm$ 5.84 [†]	-	27.73 $\pm$ 10.74	14.38 $\pm$ 13.28	146.98 $\pm$ 11.84 [†]
	BIOFIT-LP 60%	14.30 $\pm$ 8.89	-27.73 $\pm$ 10.74	-	-13.34 $\pm$ 6.40	119.26 $\pm$ 10.04 [†]
	BIOFIT-LP 75%	27.64 $\pm$ 10.59	-14.38 $\pm$ 13.28	13.34 $\pm$ 6.40	-	132.60 $\pm$ 10.86 [†]
	OFE-SLP	-104.96 $\pm$ 8.03 [†]	-146.98 $\pm$ 11.84 [†]	-119.26 $\pm$ 10.04 [†]	-132.60 $\pm$ 10.86 [†]	-
Biceps Femoris	SLP 60%	-	-17.40 $\pm$ 3.41 [†]	7.25 $\pm$ 5.70	-3.14 $\pm$ 6.75	43.55 $\pm$ 6.82 [†]
	SLP 75%	17.40 $\pm$ 3.41 [†]	-	24.65 $\pm$ 5.99**	14.26 $\pm$ 6.80	60.94 $\pm$ 6.75 [†]
	BIOFIT-LP 60%	-7.25 $\pm$ 5.70	-24.65 $\pm$ 5.99**	-	-10.39 $\pm$ 2.83*	36.29 $\pm$ 6.11 [†]
	BIOFIT-LP 75%	3.14 $\pm$ 6.75	-14.26 $\pm$ 6.80	10.39 $\pm$ 2.83*	-	46.68 $\pm$ 6.44 [†]
	OFE-SLP	-43.55 $\pm$ 6.82 [†]	-60.94 $\pm$ 6.75 [†]	-36.29 $\pm$ 6.11 [†]	-46.68 $\pm$ 6.44 [†]	-
Tibialis Anterior	SLP 60%	-	-19.78 $\pm$ 3.35 [†]	-65.39 $\pm$ 10.69 [†]	-72.54 $\pm$ 13.67 [†]	10.12 $\pm$ 9.63
	SLP 75%	19.78 $\pm$ 3.35 [†]	-	-45.61 $\pm$ 10.58**	-52.75 $\pm$ 12.87**	29.90 $\pm$ 10.28
	BIOFIT-LP 60%	65.39 $\pm$ 10.69 [†]	45.61 $\pm$ 10.58**	-	-7.14 $\pm$ 8.37	75.51 $\pm$ 10.48 [†]
	BIOFIT-LP 75%	72.54 $\pm$ 13.67 [†]	52.75 $\pm$ 12.87**	7.14 $\pm$ 8.37	-	82.65 $\pm$ 14.59 [†]
	OFE-SLP	-10.12 $\pm$ 9.63	-29.90 $\pm$ 10.28	-75.51 $\pm$ 10.48 [†]	-82.65 $\pm$ 14.59 [†]	-
Gastrocnemius	SLP 60%	-	-16.22 $\pm$ 3.80**	21.96 $\pm$ 5.64**	18.32 $\pm$ 5.72*	21.25 $\pm$ 5.78**
	SLP 75%	16.22 $\pm$ 3.80**	-	38.17 $\pm$ 5.93 [†]	34.54 $\pm$ 6.42 [†]	37.46 $\pm$ 6.87 [†]
	BIOFIT-LP 60%	-21.96 $\pm$ 5.64**	-38.17 $\pm$ 5.93 [†]	-	-6.63 $\pm$ 2.40	-0.71 $\pm$ 5.56
	BIOFIT-LP 75%	-18.32 $\pm$ 5.72*	-34.54 $\pm$ 6.42 [†]	6.63 $\pm$ 2.40	-	2.93 $\pm$ 5.28
	OFE-SLP	-21.25 $\pm$ 5.78**	-37.46 $\pm$ 6.87 [†]	0.71 $\pm$ 5.56	-2.93 $\pm$ 5.28	-

BIOFIT-LP = BIOFIT Leg Press; OFE-SLP = Classic OFE; SLP = Seated leg press; * = p value < .05; ** = p value < .01; [†] = p value < .001.

Table 4. Differentiation of peak electromyographic activity (μV) between different machines and 1RM intensities during the concentric phase.

Concentric phase		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	-49.73 $\pm$ 7.90 [†]	-26.14 $\pm$ 11.69	-46.17 $\pm$ 14.00*	149.72 $\pm$ 10.35 [†]
	SLP 75%	49.73 $\pm$ 7.90 [†]	-	23.59 $\pm$ 10.00	3.56 $\pm$ 13.40	199.45 $\pm$ 13.69 [†]
	BIOFIT-LP 60%	26.14 $\pm$ 11.69	-23.59 $\pm$ 10.00	-	-20.03 $\pm$ 6.41*	175.86 $\pm$ 13.00 [†]
	BIOFIT-LP 75%	46.17 $\pm$ 14.00*	-3.56 $\pm$ 13.40	20.03 $\pm$ 6.41*	-	195.89 $\pm$ 14.67 [†]
	OFE-SLP	-149.72 $\pm$ 10.35 [†]	-199.45 $\pm$ 13.69 [†]	-175.86 $\pm$ 13.00 [†]	-195.89 $\pm$ 14.67 [†]	-
Rectus Femoris	SLP 60%	-	-56.72 $\pm$ 8.37 [†]	-7.37 $\pm$ 11.84	-25.96 $\pm$ 14.09	121.75 $\pm$ 10.01 [†]
	SLP 75%	56.72 $\pm$ 8.37 [†]	-	49.35 $\pm$ 14.86*	30.76 $\pm$ 17.70	178.46 $\pm$ 15.09 [†]
	BIOFIT-LP 60%	7.37 $\pm$ 11.84	-49.35 $\pm$ 14.86*	-	-18.59 $\pm$ 8.61	129.11 $\pm$ 12.32 [†]
	BIOFIT-LP 75%	25.96 $\pm$ 14.09	-30.76 $\pm$ 17.70	18.59 $\pm$ 8.61	-	147.71 $\pm$ 12.19 [†]
	OFE-SLP	-121.75 $\pm$ 10.01 [†]	-178.46 $\pm$ 15.09 [†]	-129.11 $\pm$ 12.32 [†]	-147.71 $\pm$ 12.19 [†]	-
Biceps Femoris	SLP 60%	-	-18.72 $\pm$ 4.68**	7.97 $\pm$ 7.31	-4.98 $\pm$ 8.76	51.19 $\pm$ 7.05 [†]
	SLP 75%	18.72 $\pm$ 4.68**	-	26.69 $\pm$ 7.99*	13.75 $\pm$ 8.90	69.91 $\pm$ 7.75 [†]
	BIOFIT-LP 60%	-7.97 $\pm$ 7.31	-26.69 $\pm$ 7.99*	-	-12.94 $\pm$ 3.82*	43.22 $\pm$ 5.72 [†]
	BIOFIT-LP 75%	4.98 $\pm$ 8.76	-13.75 $\pm$ 8.90	12.94 $\pm$ 3.82*	-	56.17 $\pm$ 7.00 [†]
	OFE-SLP	-51.19 $\pm$ 7.05 [†]	-69.91 $\pm$ 7.75 [†]	-43.22 $\pm$ 5.72 [†]	-56.17 $\pm$ 7.00 [†]	-
Tibialis Anterior	SLP 60%	-	-18.82 $\pm$ 3.91 [†]	-22.49 $\pm$ 9.25	-39.24 $\pm$ 13.60	43.11 $\pm$ 8.65 [†]
	SLP 75%	18.82 $\pm$ 3.91 [†]	-	-3.67 $\pm$ 8.61	-20.42 $\pm$ 12.53	61.92 $\pm$ 9.58 [†]
	BIOFIT-LP 60%	22.49 $\pm$ 9.25	3.67 $\pm$ 8.61	-	-16.75 $\pm$ 9.42	68.59 $\pm$ 9.80 [†]
	BIOFIT-LP 75%	39.24 $\pm$ 13.60	20.42 $\pm$ 12.53	16.75 $\pm$ 9.42	-	82.34 $\pm$ 13.03 [†]
	OFE-SLP	-43.11 $\pm$ 8.65 [†]	-61.92 $\pm$ 9.58 [†]	-68.59 $\pm$ 9.80 [†]	-82.34 $\pm$ 13.03 [†]	-
Gastrocnemius	SLP 60%	-	-15.02 $\pm$ 4.80*	26.96 $\pm$ 7.39*	25.38 $\pm$ 7.21*	26.72 $\pm$ 7.11**
	SLP 75%	15.02 $\pm$ 4.80*	-	41.98 $\pm$ 6.56 [†]	40.40 $\pm$ 6.91 [†]	41.74 $\pm$ 6.85 [†]
	BIOFIT-LP 60%	-26.96 $\pm$ 7.39*	-41.98 $\pm$ 6.56 [†]	-	-1.59 $\pm$ 3.29	-0.24 $\pm$ 6.95
	BIOFIT-LP 75%	-25.38 $\pm$ 7.21*	-40.40 $\pm$ 6.91 [†]	1.59 $\pm$ 3.29	-	1.35 $\pm$ 6.40
	OFE-SLP	-26.72 $\pm$ 7.11**	-41.74 $\pm$ 6.85 [†]	0.24 $\pm$ 6.95	-1.35 $\pm$ 6.40	-

BIOFIT-LP = BIOFIT leg press; OFE-SLP = classic OFE; SLP = seated leg press; * = p value < .05; ** = p value < .01; [†] = p value < .001.

Table 5. Differentiation of peak electromyographic activity (μV) between different machines and 1RM intensities during the eccentric phase.

Eccentric phase		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	-27.48 $\pm$ 3.49 [†]	-10.20 $\pm$ 7.63	-18.73 $\pm$ 7.11	111.79 $\pm$ 8.78 [†]
	SLP 75%	27.48 $\pm$ 3.49 [†]	-	17.28 $\pm$ 8.74	8.75 $\pm$ 8.02	139.27 $\pm$ 9.61 [†]
	BIOFIT-LP 60%	10.20 $\pm$ 7.63	-17.28 $\pm$ 8.74	-	-8.53 $\pm$ 4.09	121.99 $\pm$ 7.41 [†]
	BIOFIT-LP 75%	18.73 $\pm$ 7.11	-8.75 $\pm$ 8.02	8.53 $\pm$ 4.09	-	130.52 $\pm$ 7.55 [†]
	OFE-SLP	-111.79 $\pm$ 8.78 [†]	-139.27 $\pm$ 9.61 [†]	-121.99 $\pm$ 7.41 [†]	-130.52 $\pm$ 7.55 [†]	-
Rectus Femoris	SLP 60%	-	-24.29 $\pm$ 6.01 ^{**}	-24.08 $\pm$ 11.08	-31.47 $\pm$ 11.64	85.86 $\pm$ 8.64 [†]
	SLP 75%	24.29 $\pm$ 6.01 ^{**}	-	0.21 $\pm$ 10.15	-7.18 $\pm$ 11.48	110.15 $\pm$ 9.63 [†]
	BIOFIT-LP 60%	24.08 $\pm$ 11.08	-0.21 $\pm$ 10.15	-	-7.39 $\pm$ 6.28	109.94 $\pm$ 9.10 [†]
	BIOFIT-LP 75%	31.47 $\pm$ 11.64	7.18 $\pm$ 11.48	7.39 $\pm$ 6.28	-	117.33 $\pm$ 10.15 [†]
	OFE-SLP	-85.86 $\pm$ 8.64 [†]	-110.15 $\pm$ 9.63 [†]	-109.94 $\pm$ 9.10 [†]	-117.33 $\pm$ 10.15 [†]	-
Biceps Femoris	SLP 60%	-	-10.97 $\pm$ 2.70 ^{**}	12.35 $\pm$ 4.19	6.41 $\pm$ 4.27	23.28 $\pm$ 4.46 [†]
	SLP 75%	10.97 $\pm$ 2.70 ^{**}	-	23.32 $\pm$ 4.43 [†]	17.38 $\pm$ 4.58 ^{**}	34.25 $\pm$ 4.15 [†]
	BIOFIT-LP 60%	-12.35 $\pm$ 4.19	-23.32 $\pm$ 4.43 [†]	-	-5.94 $\pm$ 1.51 ^{**}	10.94 $\pm$ 2.41 ^{**}
	BIOFIT-LP 75%	-6.41 $\pm$ 4.27	-17.38 $\pm$ 4.58 ^{**}	5.94 $\pm$ 1.51 ^{**}	-	16.87 $\pm$ 2.92 [†]
	OFE-SLP	-23.28 $\pm$ 4.46 [†]	-34.25 $\pm$ 4.15 [†]	-10.94 $\pm$ 2.41 ^{**}	-16.87 $\pm$ 2.92 [†]	-
Tibialis Anterior	SLP 60%	-	-19.16 $\pm$ 3.49 [†]	-102.04 $\pm$ 14.40 [†]	-104.26 $\pm$ 16.56 [†]	-15.20 $\pm$ 11.15
	SLP 75%	19.16 $\pm$ 3.49 [†]	-	-82.89 $\pm$ 15.02 [†]	-85.11 $\pm$ 16.76 [†]	3.95 $\pm$ 11.70
	BIOFIT-LP 60%	102.04 $\pm$ 14.40 [†]	82.89 $\pm$ 15.02 [†]	-	-2.22 $\pm$ 9.75	86.84 $\pm$ 13.62 [†]
	BIOFIT-LP 75%	104.26 $\pm$ 16.56 [†]	85.11 $\pm$ 16.76 [†]	2.22 $\pm$ 9.75	-	89.06 $\pm$ 17.86 [†]
	OFE-SLP	15.20 $\pm$ 11.15	-3.95 $\pm$ 11.70	-86.84 $\pm$ 13.62 [†]	-89.06 $\pm$ 17.86 [†]	-
Gastrocnemius	SLP 60%	-	-12.38 $\pm$ 2.44 [†]	17.11 $\pm$ 4.54 ^{**}	10.67 $\pm$ 4.70	10.86 $\pm$ 4.30
	SLP 75%	12.38 $\pm$ 2.44 [†]	-	29.48 $\pm$ 5.20 [†]	23.04 $\pm$ 5.32 ^{**}	23.24 $\pm$ 4.90 ^{**}
	BIOFIT-LP 60%	-17.11 $\pm$ 4.54 ^{**}	-29.48 $\pm$ 5.20 [†]	-	-6.44 $\pm$ 1.73 ^{**}	-6.25 $\pm$ 3.94
	BIOFIT-LP 75%	-10.67 $\pm$ 4.70	-23.04 $\pm$ 5.32 ^{**}	6.44 $\pm$ 1.73 ^{**}	-	0.19 $\pm$ 4.47
	OFE-SLP	-10.86 $\pm$ 4.30	-23.24 $\pm$ 4.90 ^{**}	6.25 $\pm$ 3.94	-0.19 $\pm$ 4.47	-

BIOFIT-LP = BIOFIT leg press; OFE-SLP = classic OFE; SLP = seated leg press ** = p value < .01; [†] = p value < .001.

When comparing the OFE-SLP with SLP and the OFE-SLP with BIOFIT-LP, a significantly lower activation was found in the OFE-SLP for all muscle groups, in the full stroke, concentric, and eccentric phases (ES = 0.69–1.08; moderate effect size; $p < .01$ –.001), except for the tibialis anterior as compared to SLP for the full stroke and eccentric phase (ES = 0.09–0.42; effect size between small and moderate; $p > .05$); for the gastrocnemius as compared to BIOFIT-LP for the full stroke, concentric phase, and eccentric phase (ES = 0.09–0.2; small effect size; $p > .05$); and for the gastrocnemius as compared to SLP at 60% 1RM in the eccentric phase (ES = 0.25; small effect size; $p > .05$).

When comparing the OFE-SLP with SLP and the OFE-SLP with BIOFIT-LP, a significantly lower activation was found in the OFE-SLP for all muscle groups, in the full stroke, concentric, and eccentric phases (ES = 0.2–0.5 effect size between small and moderate; $p < .01$ –.001), except for the tibialis anterior, as compared to SLP for the full stroke and eccentric phase (ES = 0.14–0.5; effect size between small and moderate; $p > .05$); for the gastrocnemius, as compared to BIOFIT-LP for the full stroke, concentric phase, and eccentric phase (ES = 0.2–0.9; effect size between small and moderate; $p > .05$); and for the gastrocnemius as compared to SLP at 60% 1RM in the eccentric phase (ES = 0.25; small effect size; $p > .05$).

5.29. DISCUSSION

The main objective of this research was to analyze and compare the EMG activity of the muscle groups of the lower limbs produced during the execution of the leg press with a traditional SLP machine, and OFE-SLP and BIOFIT-LP machines. The results showed that in all three machines, the most activated muscle group was the vastus lateralis, followed by the rectus femoris and tibialis anterior. These results coincide with those found in a similar study, in which a high activation of the vastus lateralis, as well as the rectus femoris and tibialis anterior, was observed during the use of an SLP (Gonzalez et al., 2017; Hahn, 2011; Schoenfeld et al., 2014). In light of these results, the performance of exercises involving simultaneous ankle and knee extension, regardless of the small biomechanical differences between exercises, involves the same major muscle groups (Da Silva et al., 2008). This corroborates the findings of recent studies, in which muscle electrical activity was analyzed in exercises such as the SLP, the leg

press at 45°, and the squat, finding that they all activate the same major muscle groups, despite their differences in execution, as they are all lower limb press exercises (Armstrong et al., 2022; Da Silva et al., 2008; van den Tillaar et al., 2019). Furthermore, as all exercises are performed on stable, guided machines, the core musculature may be more involved, as they rely less on the stabilizing musculature, as compared to exercises with free weights (Cotterman et al., 2005). Therefore, it is possible to proceed to the comparison of the machines with each other.

In this regard, an outstanding result of the present investigation was that when comparing machines with the same percentage of intensity, more specifically the EMG activities measured in the SLP and the BIOFIT-LP, similar percentages of activation were found both at 60% and 75% of the 1RM in the main muscle groups involved, in the full stroke, and in the concentric and eccentric phases. No previous studies have analyzed EMG activity in OFE with a selector for the intensity of the exercise, and no studies were found that compared the same model of indoor and outdoor machines, with the present study being a pioneer in this aspect. However, in other studies comparing indoor machines designed to work the same muscle group, it has been found that at similar percentages of 1RM, the EMG activity of the main muscles involved is similar (Martín-Fuentes et al., 2020b), confirming the results of the present study. In light of these results, it can be affirmed, along the same lines as previous studies, that the amplitude of the EMG was greatly dependent on intensity rather than on the execution technique for both traditional SLP and BIOFIT-LP machines (Bobet & Norman, 1982).

However, a significantly greater activation was observed in the BIOFIT-LP machine as compared to the SLP machine for the tibialis anterior at both intensities in the full stroke and concentric phase, but not the eccentric one. In contrast, the gastrocnemius showed a greater activation in the SLP as compared to the BIOFIT-LP machine at both intensities and all phases, and the biceps femoris showed greater activation in the SLP at 75% 1RM during the eccentric phase. As observed in several studies, the position of the selector of the intensity of the exercise and ergonomic and biomechanical characteristics of the equipment with respect to the joint levers condition the participation of certain muscle groups (Camara et al., 2016; Jo et al., 2022; Martín-Fuentes et al., 2020a). In this sense, the findings for the SLP machine are in line with what was found in previous studies, where it was

shown that in this machine, an increased activation of the biceps femoris and gastrocnemius was generated, especially in the push-off phase (Escamilla et al., 2001), due to the co-contraction of these muscle groups, together with the extensor musculature of the knee, to improve the anteroposterior stability of the joint in the angulations of greater instability (Escamilla et al., 2001). Another possible explanation is that the projection of the intensity of the exercise in the SLP falls forward with respect to the base of support and the support of the feet, so that the co-activation of the biceps femoris and gastrocnemius is vital for knee stabilization (Escamilla et al., 2001; Kristiansen et al., 2021). In contrast, in the BIOFIT-LP machine, the intensity of the exercise projection falls further back with respect to the base of support and foot support, which could favor the activation of the tibialis anterior as a stabilizer of the ankle joint (Uzun et al., 2011). For all of the above, in general terms, it can be stated that with the new BIOFIT-LP design, an EMG similar to that achieved with the traditional fitness room machines, such as the SLP, could be achieved. Therefore, this new machine design could provide an alternative for effective strength training, albeit outdoors and free of charge, with the advantages that this could have for the health of the population (Chow & Wu, 2019). However, the lack of previous studies analyzing this issue with OFE, and the fact that the studies that have analyzed EMG activity with traditional SLP have included fewer muscle groups than in the present investigation (Martín-Fuentes et al., 2020b), makes it necessary to conduct future research that contrasts the results of the present investigation.

Another relevant result of the present investigation was that when comparing the EMG of the BIOFIT-LP and SLP, with respect to the OFE-SLP, the machines with an external selector for the intensity of the exercise showed significantly higher values in all muscle groups, regardless of the intensity of the exercise, with a few exceptions. Despite the popularity of OFE in recent years (Chow et al., 2021; Chow & Wu, 2019; Liu et al., 2020), no previous study was found that analyzed EMG activity on this type of machine, so that its efficacy is somewhat uncertain (Mehr, 2013). However, previous studies have pointed out that intensity selection conditions fiber recruitment, and therefore the recorded signal (Cormie et al., 2011; Yavuz et al., 2015). Considering that the classic OFE line only allows working with self-weight (Liu et al., 2020), the results of the present investigation could be due to the fact that the subjects' own weight did not represent an intensity

close to their 60% or 75% of the 1RM during the use of the OFE-SLP. Therefore, in light of the results of the present investigation, the OFE-SLP machine may have a limited efficacy, given the EMG activity it generates (Mehr, 2013). Therefore, it would have little capacity to generate adaptations, especially in terms of hypertrophy in most of the population, as it is lacking the increased muscle recruitment that can potentially provide a more anabolic stimulus (Schwanbeck et al., 2020), being able to only provide a sufficient stimulus in populations with low fitness levels, such as older detrained populations (Kim et al., 2018).

However, when comparing the EMG of the OFE-SLP with respect to the other two machines, no differences were found in the tibialis anterior as compared to the SLP for the full stroke and eccentric phase; for the gastrocnemius as compared to the BIOFIT-LP for the full stroke, and the concentric and eccentric phases; and for the gastrocnemius as compared to the SLP at 60% 1RM in the eccentric phase. The discussion of this section is limited, as only one article was found that analyzed the activity of gastrocnemius and tibialis anterior at the same time during the use of guided machines for lower limb training (Hahn, 2011), developed on classic fitness center machinery, without including any type of OFE in the analysis. In any case, the function of the gastrocnemius and tibialis anterior muscle groups in this type of exercise is stabilization (Escamilla et al., 2001; Martín-Fuentes et al., 2020b), so the lack of differences in EMG between machines may be due to the fact that the execution of these exercises, when performed with guided machines, may not be greatly dependent on these stabilizers (Escamilla et al., 2001).

The second objective of this work was to determine the differences in the EMG of the muscle groups of the lower limbs at 60 and 75% of the 1RM on machines that allow selection of the intensity of the exercise (SLP and BIOFIT-LP). The results showed an increase in the EMG activity of all the muscle groups analyzed when performing at an intensity of 75% of the 1RM, compared to 60% of the 1RM, both for the full stroke and for the concentric and eccentric phases in the SLP. The results are in line with those found in previous studies, in which an increase in EMG was found with an increasing intensity (Gonzalez et al., 2017). This is because at higher intensities, the recruitment and firing frequency of the recruited motor units increases (Cormie et al., 2011; Yavuz et al., 2015).

In contrast, the BIOFIT-LP machine showed significant differences with increasing intensity only in the vastus lateralis for the full stroke and concentric

phase, in the biceps femoris for the full stroke and concentric and eccentric phases, and in the gastrocnemius for the eccentric phase. No differences were found in any of the EMG cases on this machine with an increasing intensity for the rectus femoris and tibialis anterior. The fact that differences were found in the posterior musculature in the eccentric phase could be due to the fact that this phase in this exercise is performed in favor of gravity, and the participants were asked to perform it at a controlled speed, so that in the face of an increase in the intensity, it is possible that there would be an increase in EMG activation responsible for slowing down the movement, i.e., posterior musculature (Oshikawa et al., 2018; van den Tillaar et al., 2019). In contrast, the concentric phase is performed against gravity, which might require a greater activation of the biceps femoris musculature as the main knee stabilizer (van den Tillaar et al., 2019). Regarding the vastus lateralis and rectus femoris, the intensity could have been insufficient for the recruitment of more fibers by the rectus femoris, showing differences only in the vastus lateralis. Previous studies have indicated that at high intensity (90% of the 1RM), the vastus lateralis presents greater activations than the rectus femoris (Gonzalez et al., 2017). For this same reason, the signal recorded in the tibialis anterior did not present significant differences even when increasing the intensity, indicating the lack of a different stimulus in terms of joint stabilization (Uzun et al., 2011). Based on the results of the present investigation, in general terms, an increase in the intensity could imply an increase in the recruitment of fibers of the main musculature involved, and therefore, of the adaptations that will be achieved by training with such machinery (Gonzalez et al., 2017).

The main practical application of this research is that a new line of OFE that has a series of adaptations to be able to adjust the intensity of the exercise achieves similar EMG activations to conventional gym machinery. This information is valuable for both users and trainers, as it demonstrates that this line of machines could be just as effective as conventional machinery to train lower limbs in trained young men. Most of these machines are located in free, open-access facilities, providing an opportunity for the population to do strength work in an economical way and outdoors. The present research also shows that when this type of OFE does not have a system to adjust the intensity of the exercise, a lower EMG intensity is generated, so that the use of OFE that only allows training with one's own body weight could be less effective for strength training than machines that allow an

adjustment of the intensity of the exercise in trained young men. Therefore, it would be advisable for public agencies that are investing in the installation of this OFE in public spaces to consider this in order to choose models that have an adjustment of the intensity of the exercise, thus maximizing the population that will be able to train effectively in these facilities. Regarding possible future lines of research, it would be advisable to analyze other prototypes of OFE to study the effect of different design changes on the EMG presented during their use in the different muscle groups. On the other hand, in the current study, the effect of fatigue was mitigated by allowing a minute of rest between each repetition (Von Werder et al., 2015). Even so, future studies should use one of the various methods of analysis of neuromuscular fatigue (Vøllestad, 1997) as well as zero-crossing of EMG signal (H. Kim et al., 2018). In addition, it would be recommended to replicate the study in a female population or in other age populations to analyze whether the results are replicable in other populations.

Despite the novelty of the present study with respect to previous research on the analysis of the effectiveness of OFE, the present investigation is not without limitations. First, the EMG analysis of the gluteus as a hip extensor was not included due to the location of the electrodes being incompatible with the execution of the exercise on the machines, which is performed from sedentation (SLP and BIOFIT-LP). As a second limitation, the three machines exhibited small variations in the biomechanics of execution, which are conditioned by the mechanism of each of the structures, which makes the comparison between the exercises not exact. As a third limitation, the present study did not include the maximum voluntary contraction test as a variable in the EMG analysis, nor did it record the EMG during the 1RM test, variables that could have helped to differentiate the percentage of activation of each muscle group with respect to its maximum for each of the exercises involved. However, the EMG activation tests on the different machines were performed on the same day, following a randomized order, to eliminate the effect of daily variation on this variable. As a final limitation, although an in situ goniometric analysis was used to differentiate the concentric and eccentric phase, the present study did not include a goniometric analysis of the ankle, knee, and hip joints in the data analysis, which could have helped to discern the origin of the difference in EMG activation between some of the machines.

5.30. CONCLUSIONS

It was observed that the EMG activity presented by the current OFE, designed to strengthen the lower limb musculature (OFE-SLP), is significantly lower than that of the SLP, a machine commonly used in strength training in fitness centers by trained young men. On the other hand, it was found that when some changes in the machine configuration are made to the OFE, and an external intensity of the exercise is included, as performed on the BIOFIT-LP machine, activations similar to those of the SLP are achieved in trained young men. Moreover, in general terms, a higher intensity implied a higher activation of the involved musculature in trained young men. In light of these results, OFE could be considered an alternative to traditional machines for strength work in trained young men.

5.31. PATENTS

This research includes data on a new machine for the outdoor fitness equipment line, which is in the process of patenting by the Spanish Patent and Trademark Office (code: ES2975897), as well as of an external intensity of the exercise selection system for this machine (code: ES2975886).

VI – DISCUSIÓN

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La presente tesis doctoral realizada mediante compendio se compone de cinco artículos científicos que analizan el estado de salud de las personas mayores tras el confinamiento y estudian a nivel de biomecánica y de ergonomía la maquinaria biosaludable. Estos trabajos ayudan a comprender el funcionamiento y el efecto que tienen las máquinas biosaludables sobre los usuarios que las utilizan.

El primer artículo refleja la situación en la que se encuentra la población mayor en la actualidad. Concretamente, el análisis fue realizado tras el periodo de trece semanas de restricción de movilidad acontecido a causa del confinamiento por el COVID-19. La situación del pasado 2019 a causa de la expansión del coronavirus dio lugar a un estado de confinamiento. Esta situación afectó a diferentes aspectos relacionados con la salud como la actividad física y la dieta (Visser et al., 2020). Estos se encuentran estrechamente relacionados con factores de riesgo cardiovascular y enfermedades metabólicas, tales como la hipertensión, la dislipemia o la obesidad (Bellettiere et al., 2019; Chen et al., 2020; Colpani et al., 2018).

Respecto a la actividad física, se vio reducida drásticamente. Además, este largo periodo de tiempo en el domicilio pudo conducir al aumento de comportamientos sedentarios y al empeoramiento de la aptitud física (Oliveira et al., 2022). En cuanto a la alimentación, también se vio afectada de forma negativa (Visser et al., 2020). Se produjo un aumento de la ingesta de alimentos y la adquisición de patrones menos saludables de alimentación en adultos mayores (Starr et al., 2021). La suma de una peor alimentación y una reducción de la actividad física pudo ser la causa del aumento de grasa corporal y disminución de la masa muscular en la población adulta y mayor aumentando potencialmente riesgos de fragilidad, sarcopenia y de discapacidad (Starr et al., 2021; Visser et al., 2020).

Los resultados obtenidos confirmaron la hipótesis planteada mostrando un empeoramiento de los parámetros sanguíneos de acuerdo con investigaciones previas (Perrone et al., 2021). Se encontró un empeoramiento de los valores sanguíneos de HDL tras el confinamiento. Por el contrario, únicamente los sujetos

con un estilo de vida no saludable presentaron un empeoramiento de los valores de lípidos LDL y No-HDL. Como consecuencia de lo anterior, mantener un estilo de vida saludable durante el confinamiento, que incluyese actividad física y una dieta saludable, podría disminuir la probabilidad de padecer algunos de los aspectos negativos sufridos sobre los parámetros sanguíneos (Bogataj et al., 2021; Perrone et al., 2021), reduciendo a su vez el riesgo de desarrollar enfermedades cardíacas a largo plazo (Bogataj Jontez et al., 2021). Estos hallazgos son de especial relevancia al tratarse la muestra de mujeres mayores, las cuales a causa de la edad se encuentran ante un mayor riesgo de este tipo de enfermedades (Alfie et al., 2021).

En cuanto a la presión arterial, la presión arterial sistólica aumentó significativamente con la edad. Esto puede suponer un riesgo, ya que una presión arterial sistólica elevada asociada a la edad se ha relacionado con la posible aparición de eventos cardiovasculares graves, enfermedad coronaria, ictus e insuficiencia cardíaca entre otras patologías (Ettehad et al., 2016). Por el contrario, no se encontraron cambios significativos en las variables de presión sanguínea sistólica, diastólica, ni de presión sanguínea, antes y después del confinamiento. Además, no se encontraron diferencias en estos parámetros de acuerdo al estilo de vida. La ausencia de cambios puede deberse a la brevedad del periodo de tiempo transcurrido (Veloudi & Sharman, 2018).

A igual que en estudios previos (Karatas et al., 2021), se halló un aumento significativo de la masa grasa del tronco (absoluta y porcentual), la masa grasa total (absoluta y porcentual) y el porcentaje masa grasa/talla tras el confinamiento. Teniendo en cuenta que en la población adulta y mayor la talla no cambia a corto plazo (Mahoney et al., 2018), el aumento del porcentaje de masa grasa/talla podría deberse a los cambios hallados en la masa grasa. Estudios previos han demostrado que el confinamiento conllevaba una disminución del nivel de actividad física y/o un empeoramiento de los hábitos alimentarios, afectando estos factores en mayor medida al sexo femenino (Bogataj et al., 2021; Ghosh et al., 2020; Oliveira et al., 2022; Ribeiro de Lima et al., 2021). No en vano, en esta línea la presente tesis doctoral demostró que aquellas mujeres adultas y mayores que presentaban un estilo de vida no saludable presentaban un mayor aumento significativo en aquellas variables relacionadas con la acumulación de grasa total y del tronco. Otra posible explicación pudo ser que se produjese un aumento de la masa grasa total y del tronco a causa de la edad (Coin et al., 2012).

El área de distribución de la masa grasa es un factor a tener en cuenta debido a su relación con diferentes riesgos cardiometabólicos, así como la grasa localizada en el tronco, que se asocia con un mayor riesgo de enfermedad cardiovascular (Coin et al., 2012). Por lo tanto, a la luz de los resultados del presente estudio, las mujeres mayores que presentan un estilo de vida inadecuado tendrían una mayor probabilidad de padecer este tipo de patologías.

En cuanto a la masa ósea, en general no se encontraron diferencias al comparar las variables pre y post confinamiento. Sin embargo, al dividir a las mujeres según su estilo de vida, se encontró una disminución significativa en la densidad mineral ósea del cuello femoral en aquellas con un estilo de vida no saludable. Estos cambios, en situaciones normales (sin confinamiento), pueden deberse a múltiples razones, entre las que se incluyen factores genéticos, hormonales, la nutrición y el estilo de vida (Ferrari & Rizzoli, 2005). Con respecto a este último, cabe destacar que el estilo de vida fue uno de los factores más afectados durante el confinamiento (Scarmozzino & Visioli, 2020). La principal causa puede haber sido la inactividad física y un estilo de vida sedentario (Umeda-Raffa et al., 2021). El desuso o los períodos prolongados de inactividad, provocados por el confinamiento o la ausencia de estímulos sobre el sistema óseo, favorecen la reducción de la masa ósea, haciéndola más frágil; mientras que esta puede aumentar al someterla a una carga mecánica a través del ejercicio (Umeda-Raffa et al., 2021).

Por otro lado, el confinamiento redujo la exposición al sol durante un largo período de tiempo (Umeda-Raffa et al., 2021), lo que afectó a la síntesis de vitamina D y, por tanto, repercutió negativamente en la absorción de calcio en el intestino, en el mantenimiento de niveles adecuados de calcio y fósforo para una óptima formación ósea, así como en la promoción del correcto funcionamiento de la hormona paratiroidea, que mantiene los niveles séricos de calcio (Umeda-Raffa et al., 2021). Por estas razones, la suma de estos factores puede haber sido la principal causa de la reducción de la densidad mineral ósea observada en la población que mantuvo un estilo de vida no saludable.

Las variables de fuerza mostraron un empeoramiento significativo de los resultados obtenidos en el test de extensión isocinética de rodilla tras el confinamiento. Estos resultados son coherentes con lo esperado, debido al efecto de la edad sobre la disminución de la capacidad de producir fuerza (Kirwan et al.,

2020), además de una situación de movilidad restringida y, por lo tanto, una disminución de la actividad física (Shur et al., 2021).

Por otro lado, solo las mujeres mayores con un estilo de vida no saludable mostraron un empeoramiento significativo en los resultados del test de fuerza de prensión manual. Esto puede deberse a que las mujeres mayores con un estilo de vida saludable mantuvieron su estilo de vida activo, mientras que las mujeres con un peor estilo de vida redujeron en gran medida su actividad física diaria durante el confinamiento en comparación con el período posterior al mismo, debido a las políticas de restricción de movilidad. Esto podría explicarse porque la respuesta muscular a la inactividad es más fuerte que a la actividad física (Shur et al., 2021). La pérdida de fuerza muscular, además de la ausencia de diferencias significativas en la variable Masa Magra/Talla, refuerza la idea observada en investigaciones previas, donde se comprobó que la magnitud de la pérdida de fuerza observada debido al envejecimiento y a la inactividad era mayor que el grado de pérdida de masa muscular (Shur et al., 2021). Por lo tanto, se podría decir que la edad, la inactividad y un estilo de vida no saludable durante el confinamiento promovieron la pérdida de fuerza muscular en la población estudiada.

El segundo artículo expone como la disposición sagital del raquis y la inclinación pélvica se disponen durante el uso de las máquinas biosaludables tradicionales (OFE, por sus siglas en inglés *outdoor fitness equipment*), así como el posible efecto de la proporcionalidad corporal de los usuarios. El principal hallazgo de esta investigación fue la existencia de diferencias significativas en la disposición sagital del raquis y la inclinación pélvica durante la ejecución de los ejercicios con las máquinas biosaludables tradicionales, en comparación con la posición relajada de pie en adultos de mediana edad y mayores.

En las máquinas biosaludables que se ejecutan en posición de bipedestación, como los modelos surf y paseo, se observó un incremento de la cifosis torácica al utilizar estos aparatos, sin cambios en la curvatura lumbar ni en la inclinación pélvica. Coincidiendo con estos resultados, estudios previos han demostrado que cuando se realiza un agarre frontal, con rotación interna y/o aducción del hombro, es común encontrar una mayor cifosis torácica que en posición de pie relajada (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2010; Muyor, 2015), especialmente si esta postura se acompaña de un agarre mantenido (Imagama et al., 2014; Kordi et al., 2019). Esto es especialmente relevante considerando que la

presencia de curvaturas torácicas hipercifóticas durante la ejecución de ejercicios puede conllevar una menor implicación de la musculatura principal del ejercicio, provocando un mayor acortamiento de los músculos flexores y rotadores internos del hombro, una disminución de la movilidad articular, y cambios biomecánicos y en la posición del centro de gravedad, entre otros factores (Imagama et al., 2014; Kordi et al., 2019), lo que podría aumentar el riesgo de caídas, dolor de espalda y pérdida funcional (Norasteh et al., 2019).

En las máquinas de ejercicio en posición sedente, el agarre se realiza en una posición más neutra y con menor activación de la musculatura del miembro superior, lo cual podría influir en el grado de tensión de la musculatura estabilizadora de la articulación escapulo-humeral y del área torácica, adoptándose así posturas más neutras (Imagama et al., 2014; Kordi Yoosefinejad et al., 2019). Sin embargo, en ejercicios sedentes realizados en OFE, se observó una disminución de la lordosis lumbar y de la anteversión pélvica. Estudios anteriores encontraron la misma tendencia a la disminución de la lordosis lumbar y de la anteversión pélvica al analizar la disposición de la columna y la inclinación pélvica durante ejercicios sedentes en personas mayores (Norasteh et al., 2019). Esta disposición también se observó en otras acciones deportivas que requieren ejercer fuerza desde una posición sentada (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2010; Muyor, 2015). Más específicamente, estudios previos han hallado que, en el caso de partir de una posición sentada, el gesto técnico requiere realizar un movimiento de tracción con los brazos completamente extendidos, el tronco inclinado y las rodillas semi extendidas, como ocurre en los modelos de remo y el jinete. En estos casos, se produce una adaptación en la inclinación pélvica y la disposición lumbar (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2012). Esto es especialmente relevante si se considera que las personas que adoptan una posición cifótica en la zona lumbar durante la movilización de cargas tienen una mayor probabilidad de sufrir patologías como hernias y protrusiones discales, lumbalgia, espondilólisis y espondilolistesis, entre otras (McGill et al., 2014). Por lo tanto, sería recomendable modificar el diseño de este tipo de máquinas para permitir una disposición normal de la columna lumbar durante la ejecución de ejercicios guiados (McGill et al., 2014).

Otro de los objetivos del presente estudio fue analizar si las variables antropométricas podían condicionar la disposición sagital de la columna y la

inclinación pélvica durante el uso de las OFE, encontrándose que dichas variables influían significativamente en las adaptaciones de la disposición sagital de la columna y la inclinación pélvica. Estudios previos ya habían señalado que las variables antropométricas podrían condicionar la disposición sagital de la columna al realizar acciones que implican la aplicación de fuerza (Abelleira-Lamela et al., 2020; Elsayed et al., 2018). Sin embargo, hasta el momento no se habían realizado estudios que analizaran este aspecto en las OFE.

Más concretamente, se encontró que, en general, los usuarios con mayor estatura y/o con un índice córmico más alto, aquellos cuya altura sentada es proporcionalmente mayor que la altura total, tenían más probabilidad de presentar curvaturas torácicas cifóticas, así como posiciones cifóticas en la zona lumbar y una mayor probabilidad de mostrar retroversión pélvica en las máquinas ejecutadas en posición sedente. Además, en el análisis ANCOVA, se encontró que la estatura fue una covariable que influyó significativamente en la inclinación pélvica en las OFE realizadas en posición sentada en la posición inicial y en la posición final, así como en la curvatura torácica en el modelo surf. Las diferencias en la inclinación pélvica podrían deberse a que los participantes estaban sentados en las OFE y los sujetos más altos podían realizar los agarres en una posición más erguida, requiriendo así menor inclinación pélvica, como se ha encontrado en el uso de otro tipo de equipamiento deportivo (Abelleira-Lamela et al., 2020; López-Miñarro et al., 2012; Muyor, 2015). En cuanto a la curvatura torácica, se halló que la estatura influía en el surf, pero no en la OFE paseo, a pesar de que ambos se ejecutan en bipedestación. Esto podría deberse al tipo de agarre, ya que el paseo tiene un agarre frontal más alto, mientras que el surf tiene un agarre lateral a la altura de la cadera, por lo que se requiere una mayor flexión del tronco para mantener el agarre. Estudios anteriores ya han encontrado que el número de sujetos con hipercifosis torácica es mayor en este tipo de posiciones cuando no se mantiene una adecuada higiene postural (Farrag et al., 2015; Mawston et al., 2007).

Por el contrario, los parámetros antropométricos relacionados con la dimensión transversal no influyeron en la disposición sagital del raquis en adultos de mediana edad o mayores. Esto podría deberse a que uno de los problemas de las máquinas biosaludables tradicionales en relación con la ergonomía es que no pueden ajustarse a las características antropométricas de los usuarios (Chow & Wu, 2019), a diferencia de lo que ocurre con la maquinaria fitness tradicional (Chow &

Wu, 2019). Así, es probable que en sujetos más altos o con el tronco más largo, el agarre quede bajo, viéndose obligados a realizar una hipercifosis torácica para sostenerse. La disposición de la columna torácica podría a su vez condicionar la disposición de la curvatura lumbar y la inclinación pélvica (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015), lo que explicaría la presencia de inversiones en la zona lumbar y posiciones de retroversión pélvica que acompañan a disposiciones de hipercifosis torácica, especialmente cuando la ejecución se realiza desde una posición sentada (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015). Esta tendencia al aplanamiento de la curvatura lumbar y la inclinación pélvica observada durante el uso de OFE sería contraria a la disposición ideal. En este sentido, la disposición curvada de la columna en el plano sagital es esencial, ya que la resistencia de un elemento es igual al cuadrado del número de curvaturas más uno (Kapandji, 1981). La disposición casi alineada de la columna lumbar y la inclinación pélvica reduciría la resistencia de la columna. Además, la columna es más resistente a la compresión axial y más estable con la presencia de estas curvas que sin ellas (Panjabi. et al., 1985), permitiendo una absorción eficiente de las cargas aplicadas sobre ella (Adams & Dolan, 1996; Kapandji., 1981) e incrementando la eficiencia de la musculatura paravertebral (Dickson, 2004). Por lo tanto, los desalineamientos de las curvaturas torácica y lumbar, junto con la carga externa causada por la ejecución de los ejercicios, podrían aumentar el estrés intervertebral y las cargas sobre la columna (Keller et al., 2005).

Por todo ello, sería necesario mejorar la ergonomía y rediseñar las OFE, evolucionando hacia modelos que permitan ajustar las distancias entre los apoyos de los pies, los asientos y los agarres según la talla y la estatura sentada de los adultos de mediana edad y mayores.

Otro de los objetivos del segundo artículo fue analizar si la covariable sexo influía en los cambios que se producen en la disposición sagital del raquis al utilizar las OFE. Una cuestión muy debatida es si el sexo influye en la disposición sagital de la columna. Específicamente, algunos estudios han encontrado que las mujeres tienen mayor probabilidad de presentar hiperlordosis lumbar que los hombres en la edad adulta (Bailey et al., 2016), mientras que otros han mostrado similitud en la disposición sagital entre hombres y mujeres (Endo et al., 2012; Sundaresan et al., 2009; Yeh et al., 2018). En este estudio se halló que el sexo no influyó en la disposición sagital del raquis ni en la inclinación pélvica adoptadas en las OFE. Esto

podría deberse a que otros factores están afectando las adaptaciones que se producen en la disposición sagital de la columna al usar este tipo de equipos.

En el tercer artículo el objetivo principal fue analizar el efecto de un programa de entrenamiento de fuerza utilizando OFE sobre la disposición sagital del raquis y la inclinación pélvica en adultos de mediana edad y mayores. Los resultados mostraron una reducción significativa en todas las curvaturas de la disposición sagital del raquis en la posición de pie del grupo experimental después de la intervención. Por el contrario, el grupo control no mostró diferencias significativas en las curvaturas torácica o lumbar. En ambas curvaturas, torácica y lumbar, así como en la inclinación pélvica, la reducción en el grupo experimental fue significativamente mayor que en el grupo control.

De acuerdo con los hallazgos del este estudio, investigaciones anteriores han mostrado que la realización sistemática de programas multicomponentes que incluyen ejercicios generales de resistencia, fortalecimiento de la musculatura del tronco, ejercicios de movilidad articular y estiramientos dirigidos a los músculos asociados al tronco, conducen a una reducción en las curvaturas sagitales en posición de pie, tras un período de entrenamiento de 8 semanas (González-Gálvez et al., 2019; Jang et al., 2019; Jenkins et al., 2021). De manera similar, una reciente revisión sistemática con metaanálisis concluyó que el ejercicio físico estructurado combinando fuerza/estabilización torácica, movilidad y flexibilidad, era una intervención eficaz para reducir la aparición de curvaturas torácicas hiper cifóticas. Sin embargo, se comprobó que utilizar un enfoque multicomponente puede no ser la estrategia más óptima para maximizar los cambios deseados, ya que los estudios revisados fueron de baja a moderada calidad, por lo que es necesaria más investigación acerca de la temática (Jenkins et al., 2021).

La misma tendencia se encuentra en la población mayor, donde la mayoría de los estudios han analizado los efectos de una intervención multicomponente sobre la alineación espinal (Jang et al., 2019; Jenkins et al., 2021). Sin embargo, pocos estudios han demostrado el efecto de un programa de entrenamiento basado exclusivamente en máquinas guiadas de resistencia sobre la reducción de la disposición sagital del raquis en posición de bidepestación en adultos de mediana edad y mayores (Harding et al., 2021). En ese estudio se encontró que un trabajo de todo el cuerpo con máquinas guiadas puede mejorar la cifosis torácica, pero que, por el contrario, una mala selección de máquinas guiadas como los ejercicios de

tracción del core y elevaciones verticales, así como su ejecución isométrica, pueden llevar a fracturas vertebrales (Harding et al., 2021). Otro estudio no reportó diferencias significativas, quizás atribuibles a la baja intensidad del programa de fuerza realizado con bandas elásticas (Bergström et al., 2011). Por el contrario, estudios realizados en mujeres posmenopáusicas y hombres mayores de 45 años con baja densidad mineral ósea encontraron que, tras entrenar grupos musculares similares mediante ejercicios con cargas del 80–85% de una repetición máxima, se observó una mejora significativa de $-6.7 \pm 8.2^\circ$ y $-2.3 \pm 0.8^\circ$, respectivamente, en la cifosis torácica tras ocho semanas de entrenamiento (Harding et al., 2021; Watson et al., 2019). Por el contrario, no se reportó el tamaño del efecto utilizando eta cuadrado, por lo que no fue posible comparar. Una revisión anterior indicó que la clave para generar cambios en la disposición sagital de la columna torácica podría residir en el volumen de entrenamiento y la selección de dispositivos que proporcionen una carga suficiente, especialmente cuando se trabaja la musculatura del tronco como factor sinérgico junto con el resto de los ejercicios (Bansal et al., 2014; Katzman et al., 2017). A la luz de los resultados del presente estudio, esto también parece aplicarse a las OFE, que podrían proporcionar un estímulo suficiente para generar adaptaciones en la columna.

El análisis de la disposición sagital del raquis en bipedestación es esencial. Es la posición más utilizada, especialmente en personas mayores, debido a las consecuencias que tiene sobre aspectos como el equilibrio y la probabilidad de caídas (Sinaki et al., 2005). Se ha observado que un incremento en la linealidad puede mejorar el equilibrio de las personas (Choi et al., 2011; Sinaki et al., 2005), y por lo tanto, en nuestro caso, la mejora en la linealidad tras el entrenamiento podría reducir el riesgo de caídas.

La reducción en las curvaturas sagitales y la inclinación pélvica en la posición de bipedestación después del entrenamiento de fuerza encontrada en el presente estudio podría deberse a que durante la sesión de entrenamiento se realizaron distintos ejercicios de fortalecimiento, en los que la musculatura del tronco participó como agonista o sinergista, especialmente los músculos paravertebrales, erectores espinales, dorsal ancho, romboides y parte superior de la espalda. Además, se implicó la musculatura pectoral y del hombro para mejorar su función y lograr un mayor rango de movilidad articular, factores asociados a una menor hipercifosis torácica (Abelleira-Lamela et al., 2024b; Karimizadeh et al., 2022).

Estudios anteriores han encontrado que los ejercicios de musculatura del tronco son esenciales para la corrección de desalineaciones raquídeas (González-Gálvez et al., 2019; Hrysomallis & Goodman, 2001; Marcos-Pardo et al., 2024; Ponzano et al., 2021), lo que, además de los resultados del presente estudio, demuestra que los efectos de este tipo de entrenamiento también pueden extrapolarse a la población mayor. Considerando la alta incidencia de hipercifosis e hiperlordosis en esta población (Pai et al., 2021), y sus consecuencias en distintas áreas de la salud (Wong et al., 2017), el entrenamiento de fuerza podría ser un gran recurso para reducir la incidencia de estas patologías (Wong et al., 2017). Además, se ha demostrado que sus efectos perduran en el tiempo; estudios en los que se fortalecieron los extensores espinales junto con otros tipos de ejercicios, mostraron que las mujeres con hipercifosis mantuvieron mejoras en la curvatura cifótica, la fuerza de los extensores espinales y el rendimiento físico un año después de la intervención (Pawlowsky et al., 2009). Otro estudio basado en una intervención de 3 meses con entrenamiento de baja carga y bandas elásticas encontró que, tres años después, las curvaturas sagitales del raquis no empeoraron con el envejecimiento (Katzman et al., 2021). Por esta razón, entrenar mediante OFE, que en jóvenes ha demostrado proporcionar un estímulo similar al de cargas bajas (Abelleira-Lamela et al., 2024a, 2024b), puede suponer un mayor esfuerzo en adultos, generando una intensidad que derive en beneficios sobre la disposición sagital del raquis mantenidos en el tiempo, lo cual debe estudiarse en futuras investigaciones.

Una de las novedades de este trabajo fue la inclusión de la evaluación de la influencia del entrenamiento en la disposición sagital del raquis y la inclinación pélvica también en la posición de sedestación. Sentarse es una de las posiciones más comúnmente utilizadas para el análisis del raquis. Es importante analizar esta disposición en adultos mayores, ya que esta población suele pasar largos periodos de tiempo sentada, hasta el 60% del tiempo de vigilia (Matthews et al., 2008). Se ha demostrado que la posición de sedestación produce mayor presión intradiscal que la posición de bipedestación, y que la pérdida de linealidad espinal incrementa aún más el estrés sobre el anillo fibroso, el núcleo pulposo y el hueso cortical (Cho et al., 2023). Otros estudios también hallaron que una mayor flexión lumbar aumenta la presión intradiscal y el estrés compresivo y de cizallamiento antero-posterior, lo que, junto con la sedestación prolongada con inversión de la columna lumbar, incrementa la capacidad de flexión intervertebral debido a la deformación

viscoelástica de los ligamentos del arco posterior de las vértebras (López-Miñarro et al., 2014). Por ello, las malas posturas ergonómicas al sentarse pueden comprometer aún más la inversión de la zona lumbar e incrementar la laxitud del ligamento toracolumbar, lo que puede provocar deformaciones agudas o crónicas, como ocurren si se mantienen en el tiempo estas posturas por los largos periodos que pasan sentadas las personas mayores (Matthews et al., 2008). Estos aspectos pueden afectar a la salud de adultos de mediana edad y mayores (Hrysomallis & Goodman, 2001). Por todas estas razones, estudios previos han señalado la necesidad de analizar la disposición sagital del raquis y la inclinación pélvica en distintas posiciones, más allá de la evaluación exclusiva en posición de bipedestación (Pai et al., 2021).

Estudios previos mostraron que las OFE obligan a los usuarios a adoptar ciertas posturas en las que se ve implicada la disposición sagital del raquis y la inclinación pélvica durante su uso (Abelleira-Lamela et al., 2021), pero este es el primer estudio que verifica los efectos de su uso continuado. En el presente estudio, en la posición sentada, se encontró una disminución de la lordosis lumbar en el grupo experimental, con una mayor reducción de la curva en los participantes que realizaron el trabajo de fuerza en comparación con quienes no entrenaron. Los resultados encontrados, similares a los obtenidos en posición de bipedestación, podrían deberse a que la implementación de un programa de fortalecimiento muscular reduce la incidencia de desalineaciones espinales (Dimitrijević et al., 2022; González-Gálvez et al., 2019; Jang et al., 2019; Ponzano et al., 2021), aunque este es el primer estudio en demostrar que esta mejora en la alineación espinal va más allá de la posición de bipedestación. A la luz de estos resultados, el entrenamiento de fuerza en adultos de mediana edad y mayores podría mejorar la disposición sagital del raquis tanto en posición de bipedestación como de sedestación, y también podría implicar una menor tensión discal (Cho et al., 2023) y menor deformación viscoelástica de los ligamentos del arco posterior de las vértebras (López-Miñarro et al., 2014).

Este estudio también comparó la evolución de las curvaturas en posición de bipedestación y sedestación. Se encontró que los cambios producidos en la columna mediante entrenamiento con maquinaria biosaludable tradicional se observaron en mayor medida en la posición de bipedestación que en la de sedestación. La posición de bipedestación depende en gran medida de la tolerancia muscular (Ghamkhar &

Kahlaee, 2019; Larson & Brown, 2018). Estudios previos han sugerido que una baja tolerancia muscular de los músculos extensores y estabilizadores del tronco se relaciona con una peor higiene postural en bipedestación (Ghamkhar & Kahlaee, 2019; Larson & Brown, 2018). Esto podría deberse a que, al fatigarse estos músculos, aumenta la latencia de activación y se activan menos haces de fibras musculares (Fitts, 1994; Larson & Brown, 2018). Esto conlleva a una menor oposición muscular a la gravedad, resultando en desalineamientos en la disposición sagital de la columna (O'Sullivan et al., 2002). La tolerancia muscular puede modificarse con el entrenamiento (Ghamkhar & Kahlaee, 2019; O'Sullivan et al., 2002). Más específicamente, estudios previos han encontrado que el entrenamiento de fuerza con máquinas guiadas, al generar una activación mantenida de los músculos estabilizadores del tronco como sinergistas, aumenta la tolerancia muscular de dichos músculos (Stevens et al., 2008). Esto podría favorecer su función tónica de mantener una higiene postural adecuada en posición de pie, mejorando así la disposición sagital de la columna (O'Sullivan et al., 2002).

Por el contrario, la posición sedente depende directamente de la higiene postural y, más concretamente, de la disposición pélvica (Aramaki et al., 2021; Frey et al., 2019). Estudios previos han sugerido que la inclinación pélvica es el principal factor determinante para la disposición sagital de la columna en posición sentada (Aramaki et al., 2021; Frey et al., 2019). Esto podría implicar que la tolerancia de los músculos extensores del tronco tenga menor influencia en esta posición (Kett et al., 2021). Por lo tanto, los programas que solo trabajan el fortalecimiento muscular, como en esta intervención, podrían tener poco efecto sobre la disposición sagital de la columna en posición de sedestación. Y es que, a diferencia de otros estudios, el enfoque de esta intervención no fue el trabajo directo sobre la higiene postural, sino el fortalecimiento muscular.

Por todo lo anterior, la mejora de la disposición sagital de la columna en posición sentada podría depender más de la ergonomía y la higiene postural de la persona que de aspectos intrínsecos como la tolerancia muscular (Szczygieł et al., 2017). Por otro lado, los cambios en posición de pie podrían depender más de la tolerancia muscular (Ghamkhar & Kahlaee, 2019; Larson & Brown, 2018). Esto podría explicar la causa de los cambios mostrados que se reflejan en mayor medida en la posición de pie relajada. No obstante, ante la ausencia de estudios previos que analicen los efectos del entrenamiento de fuerza sobre la disposición sagital de la

columna en posición de pie y sentada en personas mayores, se requieren más investigaciones sobre este tema

En cuanto a la relevancia clínica de los cambios encontrados en el presente estudio, investigaciones previas mostraron que una mejora de 2.8° en la angulación de la curvatura torácica era relevante desde el punto de vista clínico (González-Gálvez et al., 2021). Por lo tanto, dado que los cambios producidos por el entrenamiento fueron superiores a los 2.8° de angulación, las máquinas biosaludables tradicionales se consideran un medio eficaz para lograr una alineación adecuada de la disposición sagital de la columna. Además, dado que el ángulo de cifosis torácica puede aumentar en 2.6° en tres años, 3.9° en cuatro años y 7° en quince años en personas mayores (Koelé et al., 2020), una reducción cercana a los 5°, como se encontró en la presente investigación, podría considerarse no solo un método para frenar los efectos del paso del tiempo, sino también una mejora con respecto al cambio asociado al envejecimiento. Estas mejoras podrían conllevar beneficios como una mejora del equilibrio, una reducción del riesgo de caídas, una mayor capacidad respiratoria, un incremento de la movilidad, una disminución del dolor de espalda y de las molestias en toda la columna (Ailon et al., 2015; Arja et al., 2003; Choi et al., 2011; Imagama et al., 2013; Sinaki et al., 2005; Wong et al., 2017).

En relación con el tamaño del efecto, este estudio obtuvo un eta cuadrado de 0.432 en la variable de curvatura torácica en posición de bipedestación relajada, tras la intervención realizada con maquinaria biosaludable tradicional. Se encontró que intervenciones que consistieron en un programa de fuerza, movilidad y ejercicios posturales diseñados específicamente para tratar la hipercifosis en adultos mayores, con una distribución de entrenamiento similar de dos sesiones semanales de una hora durante 3 meses, mostraron un valor similar (tamaño del efecto: 0.419) en la variable de cifosis en bipedestación (Katzman et al., 2017). Otro estudio centrado en el entrenamiento de personas mayores de 65 años, realizado durante 6 meses con dos tipos de entrenamiento, uno enfocado en los músculos extensores de la espalda y otro grupo que realizó un programa de ejercicios para todo el cuerpo, ambos utilizando el propio peso corporal e incrementando la carga con bandas elásticas o pesos ligeros, realizando al menos una sesión semanal de entre 20 y 30 minutos, mostró resultados que contrastan con los presentados en el presente trabajo. Aunque el tamaño del efecto sobre la cifosis torácica fue mayor en el grupo que siguió el protocolo de fortalecimiento de los extensores de la espalda

en comparación con las OFE (0.62 vs. 0.432), en la curvatura lumbar y la inclinación pélvica, las máquinas biosaludables tradicionales obtuvieron un efecto mayor o similar (ES: 0.19 vs. 0.205 y 0.06 vs. 0.434, respectivamente), con una intervención de solo 8 semanas (Fukuda et al., 2020).

El cuarto artículo analiza y compara la actividad eléctrica muscular de los grupos musculares implicados al utilizar maquinaria biosaludable tradicional, maquinaria de fitness tradicional, y un nuevo modelo de maquinaria biosaludable con carga externa destinados a la musculatura de los miembros superiores.

El primer objetivo de esta investigación fue analizar y comparar la actividad electromiográfica de los grupos musculares de los miembros superiores producida al ejercitarse con la máquina fitness tradicional de pres de pecho (SCP, por sus siglas en inglés *seated chest press*), una máquina biosaludable tradicional de pres de pecho (OFE-SCP, por sus siglas en inglés *Outdoor fitness equipment seated chest press*) y una máquina de empuje perteneciente a una nueva línea de maquinaria biosaludable (BIOFIT-SCP, por sus siglas en inglés *BIOFIT Seated Chest Press*). Según estudios previos, la realización de ejercicios que implican rotación interna con abducción y flexión del hombro, junto con extensión del codo, independientemente de las diferencias biomecánicas entre ejercicios, implican a los mismos grupos musculares principales, como la musculatura pectoral, el deltoides anterior (AD, por sus siglas en inglés *anterior deltoid*) o el tríceps braquial (Cacchio et al., 2008; Stastny et al., 2017). Otros estudios han analizado la actividad electromiográfica en ejercicios como el pec deck, el press de pecho, o press de banca, comprobando que todos ellos activan los mismos grupos musculares principales, a pesar de sus diferencias técnicas, ya que todos son ejercicios de press de miembros superiores (Cacchio et al., 2008; Stastny et al., 2017; Trebs et al., 2010). Además, en todos los ejercicios realizados en máquinas estables guiadas, la musculatura estabilizadora del tronco puede estar menos implicada, al depender menos del control postural, en comparación con ejercicios con más grados de libertad de movimiento, como se comprobó en estudios previos que mostraron diferencias significativas en la activación del recto abdominal, siendo menor durante el uso de una máquina de placas en comparación con una máquina de cables (Cacchio et al., 2008). En base a esto, en la presente investigación, se optó por realizar una comparación de la actividad electromiográfica con diferentes tipos de

máquinas, de los grupos musculares directamente implicados en el movimiento, y no tanto de los músculos que pudieran estar implicados como estabilizadores.

Un hallazgo notable de esta investigación fue que, en las tres máquinas, el grupo muscular que mostró una mayor raíz cuadrada de la media (RMS, por sus siglas en inglés *root mean square*) fue el deltoides anterior durante la fase concéntrica y la cabeza lateral del tríceps braquial (LHTB, por sus siglas en inglés *lateral head of the triceps brachii*) durante la fase excéntrica en general. Estos resultados coinciden con los encontrados en trabajos similares, siendo la AD el músculo del miembro superior que mostró una mayor activación durante el uso del press de cable de pie (Signorile et al., 2017). En cuanto a la activación del LHTB, podría deberse a la necesidad de estabilización del movimiento, como se ha comprobado en trabajos anteriores en los que se registraron señales más fuertes en ejercicios con un movimiento más libre respecto a las máquinas de press de pecho para este grupo muscular (Cacchio et al., 2008).

Un resultado destacado de la presente investigación fue que al comparar la actividad electromiográfica entre máquinas con el mismo porcentaje de intensidad, más concretamente, el SCP y el BIOFIT-SCP, la porción esternal del pectoral (SP, por sus siglas en inglés *sternal pectoralis*) presentó una señal electromiográfica significativamente mayor en todas las fases registradas en el SCP con respecto al BIOFIT-SCP a las mismas intensidades relativas; mientras que la porción clavicular del pectoral (CP, por sus siglas en inglés *clavicular pectoralis*) mostró una mayor activación en el SCP con respecto al BIOFIT-SCP, pero sólo en la fase excéntrica al 75% de la 1RM. Esto puede deberse al hecho de que los haces de las partes SP y CP tienen una ventaja de reclutamiento durante la flexión glenohumeral horizontal y puede deberse a la mejor alineación de las fibras musculares con respecto a la dirección del movimiento (Albarello et al., 2022; Trebs et al., 2010) durante la ejecución del SCP, pero que las fibras no mantuvieron la misma linealidad durante la ejecución del BIOFIT-SCP. Además, en estudios previos en los que se realizó una comparación de la actividad electromiográfica de cada músculo entre ejercicios y agarres, se observó que un press de banca con un agarre al 50% de la distancia biacromial en comparación con un agarre al 150% de la distancia biacromial, presentaba una menor activación del SP (Muyor et al., 2023). Así pues, las fibras del CP y del SP pudieron colaborar en mayor medida en todas las fases en la máquina SCP con respecto a la máquina BIOFIT-SCP debido al agarre más cercano

en el ejercicio realizado en las máquinas tradicionales (Albarello et al., 2022). Teniendo en cuenta estos resultados preliminares, sigue habiendo dudas sobre la importancia de la distancia de agarre fija o adaptativa durante el uso de este tipo de máquinas sobre la activación electromiográfica en ejercicios de empuje de miembros superiores.

Continuando con la comparación entre el SCP y el BIOFIT-SCP, en el caso de los extensores del codo, la cabeza larga del tríceps braquial (LongHTB, por sus siglas en inglés *long heads of the triceps brachii*) no mostró diferencias entre máquinas a igual intensidad, mientras que el LHTB mostró mayor activación en el BIOFIT-SCP en las fases completa y concéntrica, tanto al 60% como al 75%, sin diferencias en la fase excéntrica. Diversos estudios han justificado la participación del tríceps como músculo sinergista en ejercicios de empuje de miembros superiores (Cacchio et al., 2008) y en ejercicios de empuje que aumentaban su activación elevando la frecuencia de disparo mediante la inclusión de un respaldo que mejoraba la intervención de la musculatura principal ya que reducía la dependencia de los músculos estabilizadores durante el ejercicio (Signorile et al., 2017). Sin embargo, en la mayoría de los estudios, el tríceps braquial fue analizado como grupo muscular ubicando únicamente los electrodos en un solo vientre muscular (Cacchio et al., 2008; Coratella et al., 2019; Muyor et al., 2023; Signorile et al., 2017), siendo este el primer artículo que analiza en máquinas diferentes, la activación de dos vientres musculares del tríceps braquial, el LHTB y el LongHTB. Las diferencias encontradas entre ambas máquinas en la actividad electromiográfica de la musculatura del tríceps braquial pueden estar condicionadas por la angulación de la articulación del hombro, ya que el BIOFIT-SCP implica una flexión del hombro en mayor medida, mientras que el SCP una flexión en aducción, lo que condicionaría la señal electromiográfica del tríceps en base a estudios previos (Trebs et al., 2010).

Del mismo modo, al comparar la activación electromiográfica entre el SCP y el BIOFIT-SCP, el AD mostró una mayor activación en el BIOFIT-SCP en las fases completa y concéntrica, tanto al 60% como al 75%, sin diferencias en la fase excéntrica. Esto también podría ser debido a las diferencias en la abducción del hombro entre las dos máquinas. Se ha demostrado que el AD se implica, en mayor medida, en los ejercicios en los que el movimiento principal consiste en una flexión del hombro, en comparación con aquellos en los que el movimiento principal es la

aducción horizontal del hombro (Trebs et al., 2010). En ese sentido, el movimiento en el BIOFIT-SCP se basa en una flexión del hombro y una extensión del codo con una pequeña rotación interna del hombro, mientras que el movimiento en el SCP implica una rotación interna del hombro y una extensión del codo, junto con una abducción constante del hombro. Los resultados anteriores sobre esta cuestión son contradictorios. Así, mientras que en algunos estudios se ha encontrado que al comparar diferentes tipos de máquinas de entrenamiento de fuerza de press de pecho con carga de placas y con cable, el AD no mostró diferencias significativas entre las máquinas (Signorile et al., 2017). En otros estudios, se observó como el AD aumentaba su activación durante un ejercicio de press de pecho a medida que cambiaba la inclinación del banco, lo que provocaba un aumento de la flexión del hombro (Trebs et al., 2010). Las diferencias entre estudios pueden deberse a la dependencia de la técnica de ejecución en cada una de las variantes de los ejercicios, ya que la contribución de un músculo concreto dependerá de factores como el movimiento específico realizado en la articulación y la posición anatómica del músculo (Trebs et al., 2010).

Otro resultado relevante de este estudio fue que, al comparar la actividad electromiográfica de las máquinas BIOFIT-SCP y SCP con la OFE-SCP, las máquinas equipadas con un selector de carga externo mostraron valores de la señal electromiográfica significativamente superiores en todos los grupos musculares, independientemente de la intensidad y la fase, con escasas excepciones. Por el contrario, aunque la maquinaria biosaludable ha ganado una popularidad significativa en los últimos años (Chow et al., 2021; Chow & Wu, 2019; Liu et al., 2020), no se han identificado estudios previos que hayan examinado la actividad electromiográfica utilizando este tipo de máquina, por lo que su eficacia es incierta (Mehr, 2013). Sin embargo, investigaciones previas han indicado que la elección de la intensidad influye en el reclutamiento de las fibras musculares, afectando así a la señal registrada (Cormie et al., 2011). Dado que la línea tradicional de maquinaria biosaludable sólo permite realizar ejercicios utilizando el propio peso corporal (Liu et al., 2020), los resultados de este estudio pueden atribuirse al hecho de que el peso corporal de los participantes no se correspondía con una intensidad cercana al 60% o al 75% de su 1RM al utilizar el OFE-SCP. Así, basándose en los resultados de este estudio, la OFE-SCP puede tener una eficacia limitada para generar una actividad electromiográfica significativa (Schwanbeck et al., 2020), pudiendo proporcionar

sólo un estímulo adecuado en poblaciones con bajos niveles de forma física, como los individuos mayores y desentrenados (Kim et al., 2018).

En base a los resultados encontrados en la presente investigación, la primera hipótesis de esta investigación puede ser parcialmente aceptada, ya que se encontró una mayor activación electromiográfica en SCP y BIOFIT-SCP, en comparación con OFE-SCP. Sin embargo, la segunda parte de la hipótesis, que planteaba que la activación electromiográfica entre las máquinas con selector de carga sería similar (SCP frente a BIOFIT-SCP), debe rechazarse, ya que se encontraron diferencias en cuatro de los cinco grupos musculares analizados.

El segundo objetivo de este estudio era evaluar las diferencias en la actividad electromiográfica de los grupos musculares de las extremidades superiores al 60% y al 75% de la 1RM utilizando máquinas que permiten regular la intensidad (SCP y BIOFIT-SCP). Los resultados indicaron un aumento de la actividad electromiográfica en todos los grupos musculares analizados al utilizar cargas del 75% del 1RM en comparación con el 60% del 1RM tanto para el rango completo de movimiento como durante las fases concéntrica y excéntrica en el SCP y BIOFIT-SCP. Los resultados son coherentes con estudios anteriores, que también informaron de un aumento de la actividad electromiográfica a medida que aumentaba la intensidad (Snyder & Fry, 2012). Esto ocurre porque, a intensidades más altas, se produce un aumento tanto del reclutamiento de unidades motoras como de su frecuencia de disparo (Cormie et al., 2011). Estos resultados apoyan la aceptación de la segunda hipótesis, ya que la actividad EMG registrada al 75% del 1RM fue mayor que al 60% de 1RM tanto en condiciones SCP como BIOFIT-SCP.

Por último, el quinto artículo presentado analiza y compara la actividad eléctrica muscular de los grupos musculares implicados durante el uso de maquinaria biosaludable tradicional de pres de piernas (OFE-SLP, por sus siglas en inglés *outdoor fitness equipment seated leg press*), máquina fitness tradicional de prensa de piernas (SLP, por sus siglas en inglés *seated leg press*), y un nuevo modelo de maquinaria biosaludable con carga externa destinados a la musculatura de los miembros inferiores (BIOFIT Leg Press, por nombre en inglés *BIOFIT leg press*). El objetivo principal de esta investigación fue analizar y comparar la actividad electromiográfica de los grupos musculares de los miembros inferiores producida durante la ejecución en la SLP, y las máquinas OFE-SLP y BIOFIT-LP. Los resultados mostraron que, en las tres máquinas, el grupo muscular más activado

fue el vasto lateral, seguido del recto femoral y el tibial anterior. Estos resultados coinciden con los encontrados en un estudio similar, en el que se observó una elevada activación del vasto lateral, así como del recto femoral y el tibial anterior, durante el uso de un SLP (Gonzalez et al., 2017; Hahn, 2011; Schoenfeld et al., 2014). A la luz de estos resultados, la realización de ejercicios que implican la extensión simultánea del tobillo y la rodilla, independientemente de las pequeñas diferencias biomecánicas entre ejercicios, implica a los mismos grupos musculares principales (Da Silva et al., 2008). Esto corrobora los hallazgos de estudios recientes, en los que se analizó la actividad eléctrica muscular en ejercicios como el SLP, la prensa de piernas a 45° y la sentadilla, encontrando que todos ellos activan los mismos grupos musculares mayores, a pesar de sus diferencias en la técnica de ejecución, ya que todos son ejercicios de prensa de miembros inferiores (Armstrong et al., 2022; Da Silva et al., 2008; van den Tillaar et al., 2019). Además, como todos los ejercicios se realizan en máquinas estables y guiadas, la musculatura central puede estar más implicada, ya que dependen menos de la musculatura estabilizadora, en comparación con los ejercicios con pesos libres (Cotterman et al., 2005), por lo tanto, es posible proceder a la comparación de las máquinas entre sí.

En este sentido, un resultado destacado de la presente investigación fue que, al comparar máquinas con el mismo porcentaje de intensidad, concretamente las actividades electromiográficas medidas en el SLP y en el BIOFIT-LP, se encontraron porcentajes similares de activación tanto al 60% como al 75% de la 1RM en los principales grupos musculares implicados, en el recorrido completo y en las fases concéntrica y excéntrica. No existen estudios previos que hayan analizado la actividad electromiográfica en maquinaria biosaludable con selector de carga del ejercicio, ni se han encontrado estudios que comparen el mismo modelo de máquinas indoor y outdoor, siendo el presente estudio pionero en este aspecto. Sin embargo, en otros estudios que comparan máquinas indoor diseñadas para trabajar el mismo grupo muscular, se ha encontrado que a porcentajes similares de 1RM, la actividad electromiográfica de los principales músculos implicados es similar (Martín-Fuentes et al., 2020b), confirmando los resultados del presente estudio. A la luz de estos resultados, se puede afirmar, en la misma línea que los estudios anteriores, que la amplitud de la señal electromiográfica dependió en gran medida de la intensidad más que de la técnica de ejecución tanto para las máquinas SLP tradicionales como para las BIOFIT-LP (Bobet & Norman, 1982).

Sin embargo, se observó una activación significativamente mayor en la máquina BIOFIT-LP en comparación con la máquina SLP para el tibial anterior en ambas intensidades durante el registro del rango completo y en la fase concéntrica, pero no en la excéntrica. Por el contrario, el gastrocnemio mostró una mayor activación en el SLP en comparación con la máquina BIOFIT-LP en ambas intensidades y todas las fases, y el bíceps femoral mostró una mayor activación en el SLP al 75% 1RM durante la fase excéntrica. Como se ha observado en diversos estudios, la selección de la intensidad del ejercicio y las características ergonómicas y biomecánicas del equipo con respecto a las palancas articulares condicionan la participación de determinados grupos musculares (Camara et al., 2016; Jo et al., 2022; Martín-Fuentes et al., 2020a). En este sentido, los hallazgos para la máquina SLP están en línea con lo encontrado en estudios previos, donde se demostró como en esta máquina se generaba una mayor activación del bíceps femoral y gastrocnemio, especialmente en la fase de empuje (Escamilla et al., 2001), debido a la co-contracción de estos grupos musculares, junto con la musculatura extensora de la rodilla, para mejorar la estabilidad anteroposterior de la articulación en las angulaciones de mayor inestabilidad (Escamilla et al., 2001). Otra posible explicación es que la proyección de la carga del ejercicio en el SLP cae hacia delante respecto a la base de sustentación y el apoyo de los pies, por lo que la co-activación del bíceps femoral y gastrocnemio es vital para la estabilización de la rodilla (Fragala et al., 2019; Kristiansen et al., 2021). Por el contrario, en la máquina BIOFIT-LP, la proyección de la carga del ejercicio cae más atrás respecto a la base de sustentación y apoyo de los pies, lo que podría favorecer la activación del tibial anterior como estabilizador de la articulación del tobillo (Uzun et al., 2011). Por todo lo anterior, en términos generales, se puede afirmar que con el nuevo diseño BIOFIT-LP se podría conseguir una actividad electromiográfica similar a la obtenida con las máquinas tradicionales de sala de fitness, como la SLP. Por tanto, este nuevo diseño de máquina podría suponer una alternativa para el entrenamiento efectivo de la fuerza, aunque al aire libre y de forma gratuita, con las ventajas que ello podría tener para la salud de la población (Chow & Wu, 2019). Sin embargo, la falta de estudios previos que analicen este tema sobre la maquinaria biosaludable, y el hecho de que los estudios que han analizado la actividad electromiográfica con SLP tradicional han incluido menos grupos musculares que en la presente investigación (Martín-Fuentes et al., 2020b), hace

necesario realizar futuras investigaciones que contrasten los resultados de la presente investigación.

Otro resultado relevante de la presente investigación fue que al comparar la señal electromiográfica del BIOFIT-LP y SLP, con respecto al OFE-SLP, las máquinas con selector de carga externo mostraron valores significativamente superiores en todos los grupos musculares, independientemente de la intensidad del ejercicio, con algunas excepciones. A pesar de la popularidad de la maquinaria biosaludable en los últimos años (Chow et al., 2021; Chow & Wu, 2019; Liu et al., 2020), no se ha encontrado ningún estudio previo que analice la actividad electromiográfica en este tipo de máquinas, por lo que su eficacia puede ser un tanto incierta (Mehr, 2013). Sin embargo, estudios previos han señalado que la selección de la intensidad condiciona el reclutamiento de fibras y, por tanto, la señal registrada (Cormie et al., 2011; Yavuz et al., 2015). Teniendo en cuenta que la maquinaria biosaludable tradicional sólo permite trabajar con peso propio (Liu et al., 2020), los resultados de la presente investigación podrían deberse a que el peso propio de los sujetos no representó una intensidad cercana a su 60% o 75% del 1RM durante el uso de la OFE-SLP. Por lo tanto, a la luz de los resultados de la presente investigación, la máquina OFE-SLP podría tener una eficacia limitada, dada la actividad electromiográfica generada (Mehr, 2013). Por lo tanto, tendría poca capacidad para generar adaptaciones, especialmente en términos de hipertrofia en la mayoría de la población, ya que carece del aumento del reclutamiento muscular que potencialmente puede proporcionar un estímulo más anabólico (Schwanbeck et al., 2020), siendo capaz de proporcionar un estímulo suficiente sólo en poblaciones con bajos niveles de condición física, como las poblaciones mayores desentrenadas (Kim et al., 2018).

Sin embargo, al comparar la señal electromiográfica del OFE-SLP con respecto a las otras dos máquinas, no se encontraron diferencias en el tibial anterior en comparación con el SLP para el registro del rango completo y la fase excéntrica; para el gastrocnemio en comparación con el BIOFIT-LP para el rango completo, y las fases concéntrica y excéntrica; y para el gastrocnemio en comparación con el SLP al 60% 1RM en la fase excéntrica. La discusión de este apartado es limitada, ya que sólo se encontró un artículo que analizaba la actividad del gastrocnemio y del tibial anterior al mismo tiempo durante el uso de máquinas guiadas para el entrenamiento de miembros inferiores (Hahn, 2011), desarrollado en máquinas

clásicas de gimnasio, sin incluir ningún tipo de maquinaria biosaludable en el análisis. En cualquier caso, la función de los grupos musculares gastrocnemio y tibial anterior en este tipo de ejercicios es la estabilización (Escamilla et al., 2001; Martín-Fuentes et al., 2020b), por lo que la ausencia de diferencias en la señal electromiográfica entre máquinas puede deberse a la ejecución de estos ejercicios, que, al ser realizada con máquinas guiadas, puede no depender en gran medida de estos estabilizadores (Escamilla et al., 2001).

El segundo objetivo de este trabajo fue determinar las diferencias en la señal electromiográfica de los grupos musculares de los miembros inferiores al 60 y 75% del 1RM en máquinas que permiten seleccionar la intensidad del ejercicio (SLP y BIOFIT-LP). Los resultados mostraron un aumento de la actividad electromiográfica de todos los grupos musculares analizados al realizarlo a una intensidad del 75% del 1RM, en comparación con el 60% del 1RM, tanto para el rango completo como para las fases concéntrica y excéntrica en el SLP. Los resultados están en consonancia con los encontrados en estudios anteriores, en los que se observó un aumento de la señal electromiográfica al aumentar la intensidad (Gonzalez et al., 2017). Esto se debe a que, a mayores intensidades, aumenta el reclutamiento y la frecuencia de disparo de las unidades motoras reclutadas (Cormie et al., 2011; Yavuz et al., 2015).

Por el contrario, la máquina BIOFIT-LP mostró diferencias significativas con el aumento de intensidad sólo en el vasto lateral para el registro en el rango completo y la fase concéntrica, en el bíceps femoral para el rango completo y las fases concéntrica y excéntrica, y en el gastrocnemio para la fase excéntrica. No se encontraron diferencias en ninguno de los casos de señales electromiográficas en esta máquina con una intensidad creciente para el recto femoral y el tibial anterior. El hecho de que se encontraran diferencias en la musculatura posterior en la fase excéntrica podría deberse a que esta fase en este ejercicio se realiza a favor de la gravedad, y se pidió a los participantes que la realizaran a una velocidad controlada, por lo que ante un aumento de la intensidad es posible que se produjera un aumento de la activación electromiográfica responsable de la ralentización del movimiento, es decir, de la musculatura posterior (Oshikawa et al., 2018; van den Tillaar et al., 2019). Por el contrario, la fase concéntrica se realiza contra la gravedad, lo que podría requerir una mayor activación de la musculatura del bíceps femoral como principal estabilizador de la rodilla (van den Tillaar et al., 2019). En cuanto al

vasto lateral y el recto femoral, la intensidad podría haber sido insuficiente para el reclutamiento de más fibras por parte del recto femoral, mostrando diferencias únicamente en el vasto lateral. Estudios previos han indicado que a alta intensidad (90% de la 1RM), el vasto lateral presenta mayores activaciones que el recto femoral (Gonzalez et al., 2017). Por esta misma razón, la señal registrada en el tibial anterior no presentó diferencias significativas incluso al aumentar la intensidad, indicando la ausencia de un estímulo diferente en términos de estabilización articular (Uzun et al., 2011). En base a los resultados de la presente investigación, en términos generales, un aumento de la intensidad podría implicar un aumento del reclutamiento de fibras de la principal musculatura implicada y, por tanto, de las adaptaciones que se conseguirán entrenando con dicha maquinaria (Gonzalez et al., 2017).

VII – CONCLUSIONES

VII - CONCLUSIONES

7.1. CONCLUSIONES GENERALES

1. La maquinaria biosaludable tradicional predispuso a los usuarios a la adopción de posturas las cuales comprometen la disposición sagital del raquis. Aun así, el uso de esta maquinaria en entrenamientos de fuerza durante 8 semanas a razón de 2 sesiones semanales presentó mejoras en la disposición sagital del raquis en personas adultas y mayores.
2. La maquinaria biosaludable tradicional, presentó una actividad electromiográfica significativamente menor en la musculatura implicada en el ejercicio con respecto a las máquinas con carga externa analizadas, las cuales mostraron grandes similitudes entre ellas a pesar de las diferencias en la técnica de ejecución de estos ejercicios.

7.2. CONCLUSIONES ESPECÍFICAS

1. El confinamiento tuvo un gran impacto negativo en la mayoría de los parámetros analizados en las mujeres mayores españolas: colesterol, densidad mineral ósea de cuello femoral, la masa grasa y los valores de fuerza. Además, se observó como un estilo de vida saludable podría ser un factor protector frente al aumento del colesterol LDL asociado a la edad, la disminución de colesterol HDL, el aumento de la masa grasa y la disminución de los valores de fuerza.
2. Los adultos de mediana y avanzada edad presentan desalineaciones de la columna vertebral al utilizar maquinaria biosaludable tradicional con respecto a la posición de pie. La estatura y el índice córmico condicionaron estas adaptaciones, mostrando que los sujetos con mayor estatura e índice córmico tenían mayor probabilidad de mostrar un aumento de la cifosis torácica, cifosis lumbar y retroversión pélvica.

3. Ocho semanas de dos sesiones semanales de entrenamiento de fuerza en circuito con maquinaria biosaludable tradicional mejoró la disposición sagital de la columna torácica y lumbar y la inclinación pélvica en la posición de pie, y de la curvatura lumbar en posición sentada en adultos de mediana edad y mayores.
4. Las máquinas de press de pecho sentado con selectores de carga externa analizadas mostraron de forma sistemática mayores activaciones electromiográficas en todos los grupos musculares en comparación con la máquina biosaludable tradicional. Por otro lado, otro diseño de máquina biosaludable junto a la inclusión de carga externa, obtuvieron activaciones similares a las de la SCP en la musculatura principal del ejercicio. Además, en términos generales, una mayor intensidad implicó una mayor activación de la musculatura implicada en los hombres jóvenes entrenados.
5. Las máquinas destinadas al entrenamiento de los miembros inferiores con selectores de carga externa analizadas mostraron de forma sistemática mayores activaciones electromiográficas en todos los grupos musculares en comparación con la máquina biosaludable tradicional. Por otro lado, algunos cambios en la configuración de la máquina biosaludable, y la inclusión de carga externa, obtuvieron activaciones similares a las de la SLP en hombres jóvenes entrenados. Además, en términos generales, una mayor intensidad implicó una mayor activación de la musculatura implicada en los hombres jóvenes entrenados.

7.3. GENERAL CONCLUSIONS

1. Traditional outdoor fitness equipment predisposed users to adopt postures that compromise the sagittal disposition of the spine. Even so, the use of this equipment in strength training for 8 weeks at a rate of 2 sessions per week showed improvements in the sagittal disposition of the spine in adults and older people.
2. The traditional outdoor fitness equipment presented a significantly lower electromyographic activity in the muscles involved in the exercise compared to the machines with external load analysed, which showed great similarities between them despite the differences in the execution technique of these exercises.

7.4. SPECIFIC CONCLUSIONS

1. The confinement had a large negative impact on most of the parameters analysed in the Spanish older women: cholesterol, femoral neck bone mineral density, fat mass and strength values. In addition, it was observed that a healthy lifestyle could be a protective factor against age-associated increase in LDL-cholesterol, decrease in HDL-cholesterol, increase in fat mass and decrease in strength values
2. Middle-aged and older adults have spinal misalignments when using traditional outdoor fitness equipment compared to standing. Height and formulaic index conditioned these adaptations, showing that subjects with greater height and formulaic index were more likely to show increased thoracic kyphosis, lumbar kyphosis and pelvic retroversion.
3. Eight weeks of twice-weekly circuit strength training sessions with traditional outdoor fitness equipment improved sagittal thoracic and lumbar spine disposition and pelvic tilt in the standing position, and lumbar curvature in the sitting position in middle-aged and older adults.
4. The seated chest press machines with external load selectors analysed consistently showed greater electromyographic activations in all muscle groups compared to the traditional outdoor fitness equipment. On the

other hand, another outdoor fitness equipment design, together with the inclusion of external load, obtained similar activations to the seated chest press in the main exercise musculature. Moreover, in general terms, a higher intensity implied a greater activation of the musculature involved in the trained young men.

5. The lower limb training machines with external load selectors analysed consistently showed higher electromyographic activations in all muscle groups compared to the traditional outdoor fitness equipment. On the other hand, some changes in the configuration of the outdoor fitness equipment, and the inclusion of external load, obtained activations similar to those of the seated leg press in young trained men. Moreover, in general terms, a higher intensity implied a higher activation of the involved musculature in trained young me.

IX – APLICACIONES PRÁCTICAS

VIII - APLICACIONES PRÁCTICAS

El presente apartado de aplicaciones prácticas pretende dilucidar la transferencia de los trabajos científicos de los cuales se compone la presente tesis doctoral a su aplicación y posible uso. Estos pueden ser tomados tanto por parte de la población general como por la industria con el objetivo de conseguir un uso y diseño de maquinaria de entrenamiento outdoor que cumpla con los objetivos de los usuarios, pero que a su vez cumplan con criterios de seguridad y de efectividad.

Tras el estudio de parámetros de salud y fuerza de la población se pueden proponer las siguientes aplicaciones.

1. La primera de ellas es la presentación del estado actual en el que se encuentra la población mayor. Es esencial mantener una evaluación continua en esta población en aspectos psicosociales, nutricionales, y acerca de la salud. De este modo, se aporta información relevante del estado de la población pudiendo así intervenir de forma precoz, así como tomar decisiones y evitar posibles riesgos.
2. La segunda aplicación práctica en relación con el primer estudio radica en la necesidad de la promoción de la actividad física en las personas mayores. Los datos recabados muestran un descenso de los niveles de fuerza con la edad, poniéndose de manifiesto la necesidad de implementar programas de ejercicio físico en esta población para así mantener niveles de salud óptimos.

Respecto al análisis ergonómico de la maquinaria, las aplicaciones prácticas pueden ser presentadas con una clara línea industrial. Esto es debido a que los usuarios a día de hoy no pueden cambiar la disposición de los asientos y respaldos de las máquinas biosaludables ya que son fijos, por lo que carecen de posibilidad de adaptación por su parte. Aun así, los resultados obtenidos pueden ser utilizados como posible base a la hora de promocionar y educar a los usuarios en el uso de maquinaria biosaludable y la higiene postural.

3. Respecto al diseño de estas máquinas, las modificaciones a adoptar se podrán basar en en la implementación de respaldos y asientos regulables, así como en la necesidad de realizar un estudio antropométrico de la población objetivo de esta maquinaria para así adaptarla a dichos usuarios manteniendo su eficacia y aportando una mayor seguridad.

La intervención realizada mediante maquinaria biosaludable aporta varios aspectos a destacar en este apartado.

4. La tabla 1 del tercer estudio describe la técnica de uso de algunas de las máquinas, pudiendo esta ser utilizada por los usuarios interesados en este tipo de instalaciones.
5. La principal aplicación práctica del estudio es la presentación de un protocolo de entrenamiento eficaz para la mejora de la salud de las personas mayores en cuanto a la disposición sagital del raquis.

En cuanto a los dos últimos estudios orientados al análisis electromiográfico, la principal implicación práctica es:

6. La introducción de un nuevo tipo de maquinaria biosaludable, la cual cuenta con un respaldo científico previo que verifica su eficacia en el reclutamiento de los músculos objetivo de forma similar a las máquinas fitness tradicionales. Además, su eficacia se mejoró mediante la inclusión de un sistema de selección de carga externa, permitiendo así no solo cumplir con el principio de progresión de la carga en el entrenamiento, sino que también mejorar el control de la intensidad del entrenamiento cuando se utilizan este tipo de máquinas.

X - LIMITACIONES Y FUTURAS LÍNEAS DE INVESTIGACIÓN

IX -LIMITACIONES Y FUTURAS LÍNEAS DE INVESTIGACIÓN

La presente tesis doctoral ha aportado nuevos conocimientos científicos acerca de la maquinaria biosaludable, concretamente sobre las ramas de la ergonomía y la biomecánica de estas instalaciones. Aun así, es importante reconocer los diversos tipos de limitaciones que se han encontrado durante el desarrollo de todo el proceso. El reconocimiento de las limitaciones de la presente tesis doctoral tiene como objetivo que las mismas puedan ser contempladas en futuras investigaciones, mejorando así su calidad e impulsando nuevas líneas de investigación. A continuación, se detallan las principales limitaciones.

El primer estudio, centrado en el análisis del efecto del confinamiento sobre parámetros de salud y fuerza en mujeres mayores, tiene como principal limitación que la muestra fue compuesta únicamente por mujeres. Contar con una muestra similar de ambos sexos podría haber permitido evaluar posibles diferencias en la respuesta al confinamiento en función del sexo sobre los parámetros analizados. Otra limitación importante fue la imposibilidad de disponer de un grupo control con el cual comparar dichos efectos. Sin embargo, este hecho no pudo omitirse debido a que la situación de confinamiento impuesta por el estado de alarma afectaba a toda la población.

Durante el análisis descriptivo de la disposición sagital del raquis durante el uso de la maquinaria biosaludable, la muestra de hombres no fue suficiente como para igualar el tamaño muestral del grupo de mujeres. Esto puede ser debido a la preferencia del sexo femenino por las OFE y por la práctica de ejercicio en edades avanzadas (Bergmann et al., 2021). Asimismo, únicamente se tuvo a disposición una máquina de cada modelo, y no de prototipos con diferentes disposiciones, que nos hubiesen permitido analizar la influencia de las diferentes disposiciones de las máquinas sobre la disposición sagital del raquis.

Respecto al entrenamiento mediante maquinaria biosaludable tradicional, se recomienda su réplica con la modificación de algunos matices, como su duración, comprobando así su efecto a largo plazo. Además, el protocolo podrá incluir la comparación con otras intervenciones mediante otros tipos de materiales, o maquinaria fitness tradicional. También se podrán buscar métodos para controlar

la carga externa en este tipo de máquinas, así como analizar si variables como el sexo pueden condicionar los resultados obtenidos.

En cuanto al análisis electromiográfico durante el uso de las OFE, la principal limitación fue la falta de inclusión de algunos grupos musculares. En el caso de los ejercicios destinados a la musculatura pectoral, no fue posible colocar los electrodos en la musculatura antagonista (zona de la espalda) ya que los ejercicios eran realizados en aparatos con respaldo, por lo que estos eran desplazados de su posición. En el caso de las máquinas destinadas para miembros inferiores, el glúteo no pudo ser analizado en su función de extensor de cadera durante el ejercicio debido a que el músculo mencionado se encontraba en contacto con el asiento de la máquina imposibilitando así la localización de los electrodos. Además, la biomecánica de la ejecución de las OFE era ligeramente diferente entre las máquinas, por lo que la exactitud a la hora compararlas de forma directa pudo verse reducida. Sin embargo, es importante señalar que los estudios con un componente electromiográfico a menudo pretenden analizar estas variaciones biomecánicas, proporcionando información valiosa sobre cómo diferentes equipos o variaciones dentro del mismo ejercicio afectan de forma única a la activación muscular. Por otro lado, un factor que puede comprometer la replicabilidad de los estudios es la disponibilidad de dicha maquinaria, ya que, debido a que la empresa no las ha puesto aún en venta al público, su acceso sigue siendo limitado, únicamente pudiendo acceder a través de su patente. Aun así, al ser comparada con maquinaria biosaludable tradicional y maquinaria de sala fitness indoor, es posible que mediante esos registros se puedan interpretar los resultados para ello. Otra limitación de estos estudios fue la exclusión de la prueba de contracción voluntaria máxima, por lo que fueron utilizados los valores absolutos registrados. La inclusión de esta variable podría haber aportado información sobre el porcentaje de activación de cada grupo muscular con respecto a su máximo durante cada uno de los ejercicios. Además, aunque se utilizó un electrogoniómetro para controlar la angulación de las articulaciones de la rodilla y el codo, durante el registro de la señal electromiográfica, esta no fue incluida en el análisis. Esto podría haber aportado información acerca de los ángulos articulares, la velocidad angular durante la ejecución, su relación con los patrones de reclutamiento y la comparación entre las diferentes máquinas. Respecto a la intensidad, no fue posible, regular la carga externa utilizada en las OFE tradicionales, ya que estas

funcionan mediante un sistema de palancas con el propio peso corporal del usuario. Esta limitación además fue una de las principales motivaciones que dio lugar a la nueva maquinaria con la cual es comparada en estos trabajos, aun así, es importante remarcarlo para poder ser considerado a la hora de interpretar los resultados.

Considerando las limitaciones expuestas, se abren una serie de posibles líneas de investigación con el objetivo de ampliar el conocimiento acerca de los efectos del entrenamiento con la maquinaria biosaludable. De este modo se ahondará metodológicamente en las intervenciones teniendo en cuenta posibles factores contaminantes, permitiendo así la obtención de nuevos resultados y conocimientos. Para ello se expondrán a continuación algunas de las posibles líneas de trabajo recomendadas.

Ante futuras situaciones similares al confinamiento, se ha comprobado cómo el aspecto legislativo condiciona en gran medida el desarrollo de múltiples intervenciones científicas. Es por ello que el objetivo deberá ser la evaluación de grandes grupos poblacionales, incluyendo ambos sexos y diferentes grupos de edad, para así obtener la mejor descripción posible de la población y comprobar así si factores como el sexo o la edad pueden ser determinantes sobre la salud ante estas situaciones. De este modo se podrá proceder mediante diferentes tipos de intervenciones de acuerdo a las necesidades de cada grupo poblacional.

En aquellos trabajos en los cuales se analice la ergonomía de las OFE, se deberá propiciar la participación por parte de la población de sexo masculino para obtener una mejor descripción de la población mayor en este aspecto. Además, la disposición de diferentes máquinas enriquecerá los resultados obtenidos pudiendo determinar de este modo que diseño de estas estructuras se adapta en mayor medida a la proporcionalidad de la población a la que va dirigida.

Ante el análisis biomecánico de las OFE será de gran relevancia el análisis del mayor número de grupos musculares posibles de forma simultánea para así comprender el efecto que cada una de las máquinas ejerce sobre la musculatura de los usuarios. Además, la inclusión del estudio goniométrico de las diferentes articulaciones podría ayudar a discernir el origen de las diferencias en la activación EMG entre las máquinas. Respecto a la interpretación de la señal de EMG registrada, la inclusión de una prueba de contracción voluntaria máxima de los

músculos permitirá comprobar el porcentaje de activación que se produce con respecto al máximo de cada uno de ellos.

Por último, los futuros trabajos deberían analizar de la misma forma la población de sexo femenino, así como estudiar otros métodos de análisis electromiográfico que permita así también el análisis en población mayor.

Además de las presentes limitaciones y futuras líneas de investigación, es importante señalar que dentro del proyecto al cual va asociada la presente tesis, se están desarrollando nuevos estudios acerca de los efectos agudos del entrenamiento en OFE sobre diferentes tipos de variables fisiológicas. Los hallazgos mostrados en estos estudios abrirán nuevas posibilidades y oportunidades de cara a futuras investigaciones en el campo de la maquinaria biosaludable.

XI - REFERENCIAS BIBLIOGRÁFICAS

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XII – ANEXOS

XI - ANEXOS

ANEXO 1. Aprobación del comité de ética



COMITÉ DE ÉTICA DE LA UCAM

DATOS DEL PROYECTO

Título:	"Maquinaria Bio-saludable Inteligente: Diseño y fabricación de nueva maquinaria de fitness outdoor ergonómica, eficiente, saludable y con aplicación para dispositivos móviles (App) de valoración y control del entrenamiento"	
Investigador Principal	Nombre	Correo-e
Dr.	Pablo Jorge Marcos Pardo	pmarcos@ucam.edu

INFORME DEL COMITÉ

Fecha	29/11/2019	Código	CE111908
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Tipo de Experimentación

Investigación experimental clínica con seres humanos	
Utilización de tejidos humanos procedentes de pacientes, tejidos embrionarios o fetales	
Utilización de tejidos humanos, tejidos embrionarios o fetales procedentes de bancos de muestras o tejidos	
Investigación observacional con seres humanos, psicológica o comportamental en humanos	X
Uso de datos personales, información genética, etc.	X
Experimentación animal	
Utilización de agentes biológicos de riesgo para la salud humana, animal o las plantas	
Uso de organismos modificados genéticamente (OMGs)	

Comentarios Respecto al Tipo de Experimentación

Nada Obsta

Comentarios Respecto a la Metodología de Experimentación

Nada Obsta



ANEXO 2. Consentimiento informado 1

CONSENTIMIENTO INFORMADO

Yo,, con DNI:.....

DECLARO: Código participante: _____

Haber sido informado/a del estudio y procedimientos de la investigación del Proyecto titulado: **Maquinaria Bio-saludable Inteligente: Diseño y fabricación de nueva maquinaria de fitness outdoor ergonómica, eficiente, saludable y con aplicación para dispositivos móviles (App) de valoración y control del entrenamiento.**

Los investigadores que van a acceder a mis datos personales y a los resultados de las pruebas son: **Pablo Jorge Marcos Pardo (IP), Gemma M^a Gea García, Noelia González Gálvez, Raquel Vaquero Cristóbal, Tomás Abelleira Lamela, Francisco J. Orquín Castrillón, Abraham López Vivancos y Alejandro Espeso García.**

Asimismo, he podido hacer preguntas del estudio, comprendiendo que me presto de forma voluntaria al mismo y que en cualquier momento puedo abandonarlo sin que me suponga perjuicio de ningún tipo.

CONSIENTO: _____

1.-) Someterme a las siguientes pruebas:

- **Cuestionarios básicos de recogida de información sociodemográfica.**

- **Cuestionarios de motivación y estado de ánimo.** Los instrumentos utilizados: BPNES (Cuestionario para la medición de la satisfacción con las necesidades psicológicas básicas), BREQ3 (Cuestionario de la regulación del comportamiento en ejercicio), SWLS (Escala de satisfacción con la vida), CESD-R (Escala de Depresión del Centro de Estudios Epidemiológicos) y PSQI (Índice de calidad del sueño de Pittsburg).

- **Cuestionarios para la valoración de la Actividad Física y la Salud.** Se realizará a través del cuestionario GPAQ (Global physical activity), SF-36 (Cuestionario de salud) y Cuestionario para la valoración de la alimentación.

- **Valoración de la composición corporal y estado de hidratación.** Para ello se realizarán diferentes técnicas como densitometría dual o pruebas antropométricas básicas como:

Peso y talla: El peso y la talla serán medidos con una báscula médica con tallímetro. Además, se obtendrán las medidas de hidratación y composición ósea y muscular a través de bioimpedancia.

Pliegues, perímetros, diámetros básicos y longitudes siguiendo las recomendaciones dadas por la Asociación Internacional para la Valoración Antropométrica (ISAK, 2019).

- **Valoración de la condición física y la autonomía funcional** a través de test de campo como las baterías GDLAM y SPPB. Compuestas por los test: test de caminar 10 metros, levantarse de una posición sentada cinco veces, ascender desde una posición de decúbito ventral, levantarse de una silla y paseando por la casa y finalmente, ponerse y quitarse una camiseta.

Además, se incluirán otros test relacionados con el mantenimiento del equilibrio estático y dinámico (Prueba de equilibrio en tándem, prueba de soporte de una pierna y tiempo en levantarse de una silla y recorrer una distancia de 3 metros), la valoración de la fuerza y la potencia muscular mediante: test de dinamometría, test de fuerza máxima isométrica (en bíceps y cuádriceps) y potencia muscular, valoración de la flexibilidad y disposición sagital del raquis.

También se medirá la activación eléctrica muscular y la contracción máxima voluntaria en las diferentes máquinas para evaluar la efectividad del entrenamiento en parques biosaludables.

- Por último, es necesario para la realización de estos procedimientos que solicitamos su consentimiento para: En algunos casos la toma de imágenes, como fotos o videos. Sirven para documentar mejor el proceso de medición y toma de tiempos y resultados obtenidos. También pueden usarse para fines docentes de difusión del conocimiento científico. En cualquier caso, serán usadas siempre que usted dé su autorización, quedando en todo momento su identidad siempre preservada de forma confidencial de acuerdo con el siguiente párrafo:

2.-) El uso de los datos obtenidos según lo indicado en el párrafo siguiente:

En cumplimiento del Reglamento (UE) 2016/679 del Parlamento Europeo y del Consejo, de 27 de abril de 2016 y Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y Garantía de los Derechos Digitales, le comunicamos que la información que ha facilitado y la obtenida como consecuencia de las exploraciones a las que se va a someter pasará a formar parte del fichero automatizado INVESOCIAL, cuyo titular es la FUNDACIÓN UNIVERSITARIA SAN ANTONIO, con la finalidad de INVESTIGACIÓN Y DOCENCIA EN LAS ÁREAS DE CONOCIMIENTO CIENCIAS SOCIALES, JURÍDICAS, DE LA EMPRESA Y DE LA COMUNICACIÓN. Tiene derecho a acceder a esta información y cancelarla o rectificarla, dirigiéndose al domicilio de la entidad, en Avda. de los Jerónimos de Guadalupe 30107 (Murcia). Esta entidad le garantiza la adopción de las medidas oportunas para asegurar el tratamiento confidencial de dichos datos.

En Guadalupe (Murcia) a de de 20

El investigador,



Fdo:.....

Fdo: Pablo Jorge Marcos Pardo

ANEXO 3. Consentimiento informado 2.**CONSENTIMIENTO INFORMADO**

Código:

Yo, D. / D^a, con DNI**DECLARO:**

- Haber sido informado/a del estudio y procedimiento de investigación del Proyecto: Maquinaria bio-saludable inteligente: Diseño y fabricación de nueva maquinaria de fitness Outdoor ergonómica, eficiente, saludable y con aplicación para dispositivos móviles (APP) de valoración y control del entrenamiento.
- He podido hacer preguntas del estudio, comprendiendo que me presto de forma voluntaria y que en cualquier momento puedo abandonar sin que me suponga perjuicio de ningún tipo.

PRESTO CONSENTIMIENTO:

- Al tratamiento de los datos que deriven del presente proyecto, con fines estadísticos, científicos o docentes, lo cual se llevará a cabo mediante procesos adecuados de disociación de datos que impidan su identificación.
- A la toma de imágenes (fotos y/o vídeos) a efectos de documentar el caso durante la realización del Estudio y para fines docentes y de investigación de difusión del conocimiento científico del presente Proyecto de Investigación.
- Para someterme a las siguientes pruebas:
 - Cuestionarios básicos de recogida de información sociodemográfica.
 - Cuestionario para la valoración de la Calidad de vida relacionada con la Salud (SF-36), cuestionario de adherencia a la dieta mediterránea y satisfacción con la vida.
 - Valoración de la composición corporal mediante densitometría (DEXA).
 - Valoración de la talla, peso y tensión arterial.
 - Valoración de la fuerza isométrica máxima de extensión de rodilla y flexión de bíceps.
 - Valoración de la fuerza de prensión manual.
 - Valoración de la capacidad funcional mediante los test Chair Satnd test, velocidad de la marcha, Time up and Go test y la Batería de test de funcionalidad Short Physical Performance Battery (SPPB).
 - Valoración de la disposición sagital del raquis en bipedestación y sedestación.



Entiendo que seré asignado a un grupo experimental de práctica de actividad física o grupo control para el desarrollo de la fase experimental que tendrá una duración de 8 semanas aproximadamente.

USO DE LOS DATOS DERIVADOS DEL ESTUDIO

De acuerdo con lo dispuesto en la Ley Orgánica 15/1999, de Protección de Datos de Carácter Personal, en cualquier momento usted puede ejercitar sus derechos de acceso, rectificación, cancelación y oposición, enviando una solicitud por escrito acompañada de una fotocopia de documento oficial que lo identifique a la Universidad Católica San Antonio de Murcia, Avenida de los Jerónimos, 135, 30107 Guadalupe (Murcia).

En Guadalupe (Murcia) a de De 2021

Dra. Noelia González Gálvez

Firma de voluntario

Firma investigador principal 1

Dra. Ciencias de la Actividad Física y del Deporte

Dr. Pablo J. Marcos Pardo

Firma investigador principal 2

Dr. Ciencias de la Actividad Física y del Deporte

ANEXO 4. Consentimiento informado 3



CONSENTIMIENTO INFORMADO

Yo,, con DNI:.....

DECLARO:

Haber sido informado/a del estudio y procedimientos de la investigación del Proyecto titulado: **Maquinaria bio-saludable inteligente: diseño y fabricación de nueva maquinaria de fitness outdoor ergonómica, eficiente, saludable y con aplicación para dispositivos móviles (App) de valoración y control del entrenamiento** [código RTC-2017-6145-1].

Los investigadores que van a acceder a mis datos personales y a los resultados de las pruebas son: **Noelia González Gálvez (IP), Pablo Jorge Marcos Pardo, Francisco Esparza Ros, Tomás Abelleira Lamela, Alejandro Espeso García, Francisco Javier Orquín Castrillón y Raquel Vaquero Cristóbal.**

Esta investigación está orientada al análisis de los efectos agudos durante el uso de diferente maquinaria destinada al entrenamiento, así como de una nueva gama de maquinaria biosaludable (BIOFIT-Park). Para ello, este proyecto ha sido aprobado previamente por un comité de ética institucional (CE111908). Todos los datos recabados serán utilizados únicamente con fines científicos, siempre de forma anónima, y confidencial

Asimismo, he podido hacer preguntas del estudio, comprendiendo que me presto de forma voluntaria al mismo y que en cualquier momento puedo abandonarlo sin que me suponga perjuicio de ningún tipo.

CONSIENTO:

1.-) Someterme a las siguientes pruebas:

- **Cuestionarios básicos de recogida de información sociodemográfica.**

- **Cuestionarios para la valoración de la Actividad Física y la Salud.** Se realizará a través del cuestionario GPAQ (Global Physical Activity) y PAR-Q (cuestionario de aptitud para la actividad física), PSQI (Índice de calidad del sueño de Pittsburg).

- **Medición antropométrica, valoración de la composición corporal y estado de hidratación.** Para ello se realizarán diferentes técnicas antropométricas básicas como: Composición corporal mediante bioimpedancia, talla y diferentes medidas antropométricas siguiendo los protocolos propuestos por la Sociedad Internacional para el Avance de la Cineantropometría (ISAK). Para ello se utilizará báscula de bioimpedancia, tallímetro, cinta antropométrica, antropómetro y segmómetro.

- **Análisis electromiográfico** durante el uso de diferentes máquinas destinadas al entrenamiento de fuerza. Esta prueba consiste en analizar la actividad eléctrica muscular durante diferentes acciones durante el uso de diferente material deportivo. El equipamiento a analizar se compondrá de máquinas de sala de musculación marca Technogym®, maquinaria biosaludable de la empresa Entorno Urbano® y la nueva maquinaria biosaludable.



-**Valoración de la fuerza** y la potencia muscular. Para ello se realizarán diferentes pruebas para el análisis de fuerza en las máquinas seleccionadas. Se comenzará con la estimación de la carga máxima de cada persona (RM) en las diferentes máquinas mediante una prueba progresiva basada en el perfil fuerza-velocidad. Además, se valorará la contracción voluntaria máxima de forma isométrica mediante una galga extensiométrica por lo que las cargas durante las pruebas estarán controladas en todo momento y adaptadas a cada sujeto.

Por último, es necesario para la realización de estos procedimientos que solicitamos su consentimiento para: En algunos casos la toma de imágenes, como fotos o videos. Sirven para documentar mejor el proceso de medición y toma de tiempos y resultados obtenidos. También pueden usarse para fines docentes de difusión del conocimiento científico. En cualquier caso, serán usadas siempre que usted dé su autorización, quedando en todo momento su identidad siempre preservada de forma confidencial de acuerdo con el siguiente párrafo:

2.-) El uso de los datos obtenidos según lo indicado en el párrafo siguiente:

En cumplimiento del Reglamento (UE) 2016/679 del Parlamento Europeo y del Consejo, de 27 de abril de 2016 y Ley Orgánica 3/2018, de 5 de diciembre, de Protección de Datos Personales y Garantía de los Derechos Digitales, le comunicamos que la información que ha facilitado y la obtenida como consecuencia de las exploraciones a las que se va a someter pasará a formar parte del fichero automatizado INVESOCIAL, cuyo titular es la FUNDACIÓN UNIVERSITARIA SAN ANTONIO, con la finalidad de INVESTIGACIÓN Y DOCENCIA EN LAS ÁREAS DE CONOCIMIENTO CIENCIAS SOCIALES, JURÍDICAS, DE LA EMPRESA Y DE LA COMUNICACIÓN. Tiene derecho a acceder a esta información y cancelarla o rectificarla, dirigiéndose al domicilio de la entidad, en Avda. de los Jerónimos de Guadalupe 30107 (Murcia). Esta entidad le garantiza la adopción de las medidas oportunas para asegurar el tratamiento confidencial de dichos datos.

En Guadalupe (Murcia) a de de 202

El/la participante,

La investigadora principal,

Fdo:.....

Fdo: Dra. Noelia González Gálvez

ANEXO 5. Cuestionario Sociodemográfico 1

LEA ATÉNTAMENTE

INFORMACIÓN E INSTRUCCIONES

Sociodemográfico

A continuación, se le van a realizar una serie de preguntas, por favor, responda a todas con la mayor sinceridad posible. No deje ninguna cuestión sin contestar. Muchas gracias por su colaboración.

Todos sus datos personales, así como sus respuestas, se rigen bajo la Ley 3/2018 de 5 de diciembre, de Protección de Datos Personales y Garantía de los derechos Digitales, lo que garantiza su confidencialidad.

1.Género:

☐ Masculino☐ Femenino

2.Edad:

_____ años

3.Estado Civil

☐ Soltero-a☐ Casado-a/Pareja de hecho☐ Casado-a/Pareja de hecho + de 1 vez☐ Separado-a/Divorciado-a☐ Viudo-a

4. Nacionalidad/Lugar residencia

Indicar país y lugar de residencia:

5.Grupo étnico

☐ Caucásico☐ Asiático☐ Afroamericano☐ Otros. Especificar _____

6.Ocupación laboral

☐ Empleado a tiempo completo☐ Empleado a tiempo parcial☐ Desempleado☐ Trabajador por cuenta propia☐ Estudiante☐ Retirado

7.Nivel educativo

☐ Sin estudios☐ Estudios básicos o primarios*(Graduado Escolar)*☐ Estudios secundarios *(ESO,**Bachillerato)*☐ Educación superior por debajode estudios universitarios *(Ciclo**formativo de grado medio/superior)*☐ Estudios universitarios

8.Viviendo o no en compañía

☐ Viviendo con su esposa/o☐ Viviendo con un compañero/a☐ Viviendo sólo/a

9. Número de caídas en el último año (desde este momento): _____

10. Pérdida de peso corporal en el último año (desde este momento): _____ Kg

12. ¿Tiene alguna enfermedad o problema de salud crónicos o de larga duración? (Se entiende por larga duración si el problema de salud o enfermedad ha durado o se espera que dure 6 meses o más).

- ☐ Sí
- ☐ No
- ☐ No sabe/No contesta

13. A continuación, se le van a mostrar en una lista una serie de enfermedades o problemas de salud. Por favor, conteste si ha padecido o padece alguna de ellas.

	¿Alguna vez ha padecido?		¿La ha padecido en los últimos 12 meses?		¿Le ha dicho un médico que la padece?	
	SI	NO	SI	NO	SI	NO
1.Tensión alta						
2.Infarto de miocardio						
3.Otras enfermedades del corazón						
4.Varices en las piernas						
5.Artrosis, artritis o reumatismo						
6.Dolor de espalda crónico (cervical)						
7.Dolor de espalda crónico (lumbar)						
8.Alergia crónica (asma alérgica excluida)						
9.Asma						
10.Bronquitis crónica, enfisema, enfermedad pulmonar obstructiva crónica (EPOC)						
11.Diabetes						
12.Úlcera de estómago o duodeno						
13.Incontinencia urinaria						

13. A continuación, se le van a mostrar en una lista una serie de enfermedades o problemas de salud. Por favor, conteste si ha padecido o padece alguna de ellas.

	¿Alguna vez ha padecido?		¿La ha padecido en los últimos 12 meses?		¿Le ha dicho un médico que la padece?	
	SI	NO	SI	NO	SI	NO
14.Colesterol alto						
15.Cataratas						
16.Problemas crónicos de piel						
17.Estreñimiento crónico						
18.Cirrosis, disfunción hepática						
19.Depresión crónica						
20.Ansiedad crónica						
21.Parkison						
22.Demencia/Alzheimer						
23.Embolia, infarto cerebral, hemorragia cerebral						
24.Migraña o dolor de cabeza frecuente						
25.Hemorroides						
26.Cáncer/ Tumores malignos						
26.a. ¿Dónde? (indicar origen)						
27.Osteoporosis						
28.Problemas de tiroides						
29.Problemas de próstata (sólo hombres)						
30.Problemas del periodo (sólo mujeres)						
31.Lesiones o defectos permanentes causados por un accidente						
32.Síndrome de apnea del sueño						
Otras (indicar)						

ANEXO 6. Cuestionario sociodemográfico 2



CUESTIONARIOS

Responda a las siguientes preguntas con la mayor sinceridad. No existen preguntas bien o mal contestadas. No dejes ninguna pregunta sin responder.

¡Muchas gracias!

1. Género	2. Edad: ____ años	3. Estado civil
☐ Masculino		☐ Soltero/a
☐ Femenino		☐ Casado/a o Pareja de hecho
4. Nacionalidad: _____		☐ Separado/a o divorciado/a
Municipio de residencia: _____		☐ Viudo/a
5. Actividad física		7. Nivel de estudios
¿Práctica algún tipo de actividad física (caminar, aeróbic, gimnasia, centro deportivo, Pilates, correr, etc.)? _____		☐ Sin estudios
¿Cuál? _____		☐ Básicos (Graduado escolar)
¿Con qué frecuencia? _____		☐ Secundarios (ESO, bachillerato)
¿Cuánto tiempo? _____		☐ Superiores (ciclos formativos/grado medio o superior)
		☐ Estudios universitarios
6. Ocupación laboral		8. Viviendo o no en compañía
☐ Empleado a tiempo completo		☐ Con su esposo/a
☐ Empleado a tiempo parcial		☐ Con un compañero/a
☐ Desempleado		☐ Sólo/a
☐ Trabajador por cuenta propia		
☐ Retirado		
9. Número de caídas en el último año (desde este momento): _____		
10. Pérdida de peso corporal en el último año (desde este momento): _____ Kg		



11. Indica los medicamentos que toma usualmente, la frecuencia y con qué objetivo los toma (si no recuerda el nombre del medicamento indique su objetivo y frecuencia. Ejemplo: Medicación diaria para controlar la tensión arterial; ibuprofeno unas tres veces al mes para dolor de espalda).

12. Indique si ha padecido o padece alguna de las siguientes enfermedades.

	¿Alguna vez ha padecido?		¿La ha padecido en los últimos 12 meses?		¿Le ha dicho un médico que la padece?	
	Si	No	Si	No	Si	No
1. Tensión alta						
2. Infarto de miocardio						
3. Otras enfermedades del corazón						
4. Varices en las piernas						
5. Artrosis, artritis o reumatismo						
6. Dolor de espalda crónico (cervical)						
7. Dolor de espalda crónico (lumbar)						
8. Alergia crónica (asma alérgica excluida)						
9. Asma						
10. Bronquitis crónica, enfisema, enfermedad pulmonar obstructiva crónica (EPOC)						
11. Diabetes						
12. Úlceras de estómago y duodeno						
13. Incontinencia urinaria						



	¿Alguna vez ha padecido?		¿La ha padecido en los últimos 12 meses?		¿Le ha dicho un médico que la padece?	
	Si	No	Si	No	Si	No
14. Colesterol alto						
15. Cataratas						
16. Problemas crónicos de piel						
17. Estreñimiento crónico						
18. Cirrosis, disfunción hepática						
19. Depresión crónica						
20. Ansiedad crónica						
21. Parkinson						
22. Demencia/Alzheimer						
23. Embolia, infarto cerebral, hemorragia cerebral						
24. Migraña o dolor de cabeza frecuente						
25. Hemorroides						
26. Cáncer/tumores malignos						
26. ¿Dónde? (indicar origen)						
27. Osteoporosis						
28. Problemas de tiroides						
29. Problemas de próstata (solo hombres)						

ANEXO 7. Cuestionario sociodemográfico 3

8/5/25, 10:13

Bloque de Cuestionarios

Bloque de Cuestionarios

A continuación encontrará el bloque de cuestionarios perteneciente al proyecto “Maquinaria bio-saludable inteligente: diseño y fabricación de nueva maquinaria de fitness outdoor ergonómica, eficiente, saludable y con aplicación para dispositivos móviles (App) de valoración y control del entrenamiento” [código RTC-2017-6145-1], dentro de la Convocatoria Retos-Colaboración del Programa Estatal de Investigación, Desarrollo e Innovación.

Esta investigación está orientada al análisis electromiográfico de la maquinaria biosaludable, la maquinaria fitness tradicional, y la nueva gama de maquinaria biosaludable. Para ello, este proyecto ha sido aprobado previamente por un comité de ética institucional (CE111908). Todos los datos recabados serán utilizados únicamente con fines científicos, siempre de forma anónima, y confidencial.

* Indica que la pregunta es obligatoria

1. Correo *

2. Nombre y apellidos *

3. DNI *

4. Fecha de nacimiento *

Ejemplo: 7 de enero del 2019

5. Teléfono de contacto *

8/5/25, 10:13

Bloque de Cuestionarios

A continuación se realizarán unas preguntas acerca de su experiencia en el entrenamiento de fuerza, con el uso de maquinaria guiada, y sobre posibles lesiones y patologías

6. ¿Practica algún tipo de actividad física de forma regular? (2 o más veces a la semana) *
- _____
7. En caso afirmativo, indique: Tipo de actividad, frecuencia semanal y duración por sesión.
- _____
8. ¿Tiene experiencia en el entrenamiento de fuerza? Si su respuesta es "No" puede seguir con las preguntas acerca de su estado de salud *
- _____
9. En caso afirmativo indique de forma aproximada el tipo de entrenamiento (Entrenamiento en sala, calistenia, powerlifting...) la frecuencia semanal, y la experiencia (Años)
- _____
10. Dentro del entrenamiento de fuerza ¿Tiene experiencia con el uso de maquinaria guiada fitness?
- _____
11. Indique de forma aproximada pesos que movilizase de forma reciente junto a repeticiones en el ejercicio de press de banca, máquina de chest press o similar. Por ejemplo (10 repeticiones con 60 kg)
- _____

8/5/25, 10:13

Bloque de Cuestionarios

12. Indique de forma aproximada pesos que movilizase de forma reciente junto a repeticiones en el ejercicio de sentadilla, prensa de piernas o similar.
Por ejemplo (8 repeticiones con 70kg)

13. ¿Alguna vez le ha diagnosticado un médico una enfermedad cardíaca, recomendándole que solo haga actividad física supervisada por personal sanitario? *

14. ¿Tiene dolores en el pecho producidos por la actividad física? *

15. ¿Ha notado dolor en el pecho durante el último mes? *

16. ¿Tiende a perder el conocimiento, o el equilibrio, como resultado de mareos? *

17. ¿Alguna vez le ha recetado el médico algún fármaco para la presión arterial u otro problema cardiocirculatorio? *

18. ¿Tiene alguna alteración ósea o articular que podría agravarse por la actividad física propuesta? *

8/5/25, 10:13

Bloque de Cuestionarios

19. ¿Tiene conocimiento, por experiencia propia, o debido al consejo de algún médico, de cualquier otra razón física que le impida hacer ejercicio sin supervisión médica?



Este contenido no ha sido creado ni aprobado por Google.

Google Formularios

ANEXO 8. Cuestionario GPAQ

GPAQ

Actividad física			
A continuación voy a preguntarle por el tiempo que pasa realizando diferentes tipos de actividad física. Le ruego que intente contestar a las preguntas aunque no se considere una persona activa. Piense primero en el tiempo que pasa en el trabajo, que se trate de un empleo remunerado o no, de estudiar, de mantener su casa, de cosechar, de pescar, de cazar o de buscar trabajo <i>[inserte otros ejemplos si es necesario]</i>. En estas preguntas, las "actividades físicas intensas" se refieren a aquellas que implican un esfuerzo físico importante y que causan una gran aceleración de la respiración o del ritmo cardíaco. Por otra parte, las "actividades físicas de intensidad moderada" son aquellas que implican un esfuerzo físico moderado y causan una ligera aceleración de la respiración o del ritmo cardíaco.			
Pregunta	Respuesta	Código	
En el trabajo			
49	¿Exige su trabajo una actividad física intensa que implica una aceleración importante de la respiración o del ritmo cardíaco, como <i>[levantar pesos, cavar o trabajos de construcción]</i> durante al menos 10 minutos consecutivos? <i>(INSERTAR EJEMPLOS Y UTILIZAR LAS CARTILLAS DE IMÁGENES)</i>	Si 1 No 2 Si No, Saltar a P 4	P1
50	En una semana típica, ¿cuántos días realiza usted actividades físicas intensas en su trabajo?	Número de días	P2
51	En uno de esos días en los que realiza actividades físicas intensas, ¿cuánto tiempo suele dedicar a esas actividades?	Horas : minutos : hrs mins	P3 (a-b)
52	¿Exige su trabajo una actividad de intensidad moderada que implica una ligera aceleración de la respiración o del ritmo cardíaco, como caminar deprisa <i>[o transportar pesos ligeros]</i> durante al menos 10 minutos consecutivos? <i>(INSERTAR EJEMPLOS Y UTILIZAR LAS CARTILLAS DE IMÁGENES)</i>	Si 1 No 2 Si No, Saltar a P7	P4
53	En una semana típica, ¿cuántos días realiza usted actividades de intensidad moderada en su trabajo?	Número de días	P5
54	En uno de esos días en los que realiza actividades físicas de intensidad moderada, ¿cuánto tiempo suele dedicar a esas actividades?	Horas : minutos : hrs mins	P6 (a-b)
Para desplazarse			
En las siguientes preguntas, dejaremos de lado las actividades físicas en el trabajo, de las que ya hemos tratado. Ahora me gustaría saber cómo se desplaza de un sitio a otro. Por ejemplo, cómo va al trabajo, de compras, al mercado, al lugar de culto <i>[insertar otros ejemplos si es necesario]</i>			
55	¿Camina usted o usa usted una bicicleta al menos 10 minutos consecutivos en sus desplazamientos?	Si 1 No 2 Si No, Saltar a P 10	P7
56	En una semana típica, ¿cuántos días camina o va en bicicleta al menos 10 minutos consecutivos en sus desplazamientos?	Número de días	P8
57	En un día típico, ¿cuánto tiempo pasa caminando o yendo en bicicleta para desplazarse?	Horas : minutos : hrs mins	P9 (a-b)

GPAQ

SECCIÓN PRINCIPAL: Actividad física (en el tiempo libre) sigue.		
Pregunta	Respuesta	Código
58 ¿En su tiempo libre, practica usted deportes/fitness intensos que impliquen una aceleración importante de la respiración o del ritmo cardíaco como [correr, jugar al fútbol] durante al menos 10 minutos consecutivos? (INSERTAR EJEMPLOS Y UTILIZAR LAS CARTILLAS DE IMÁGENES)	Si 1 No 2 Si No, Saltar a P 13	P10
59 En una semana típica, ¿cuántos días practica usted deportes/fitness intensos en su tiempo libre?	Número de días	P11
60 En uno de esos días en los que practica deportes/fitness intensos, ¿cuánto tiempo suele dedicar a esas actividades?	Horas : minutos : hrs mins	P12 (a-b)
61 ¿En su tiempo libre practica usted alguna actividad de intensidad moderada que implique una ligera aceleración de la respiración o del ritmo cardíaco, como caminar deprisa, [ir en bicicleta, nadar, jugar al volleyball] durante al menos 10 minutos consecutivos? (INSERTAR EJEMPLOS Y UTILIZAR LAS CARTILLAS DE IMÁGENES)	Si 1 No 2 Si No, Saltar a P16	P13
62 En una semana típica, ¿cuántos días practica usted actividades físicas de intensidad moderada en su tiempo libre?	Número de días	P14
63 En uno de esos días en los que practica actividades físicas de intensidad moderada, ¿cuánto tiempo suele dedicar a esas actividades?	Horas : minutos : hrs mins	P15 (a-b)
Comportamiento sedentario		
La siguiente pregunta se refiere al tiempo que suele pasar sentado o recostado en el trabajo, en casa, en los desplazamientos o con sus amigos. Se incluye el tiempo pasado [ante una mesa de trabajo, sentado con los amigos, viajando en autobús o en tren, jugando a las cartas o viendo la televisión], pero no se incluye el tiempo pasado durmiendo. (INSERTAR EJEMPLOS) (UTILIZAR LAS CARTILLAS DE IMÁGENES)		
64 ¿Cuánto tiempo suele pasar sentado o recostado en un día típico?	Horas : minutos : hrs mins	P16 (a-b)



Organización
Mundial de la Salud

ANEXO 9. Cuestionario PREDIMED



CUESTIONARIO DE ADHERENCIA A LA DIETA MEDITERRÁNEA

1	¿Usa usted el aceite de oliva principalmente para cocinar?	Si / No
2	¿Toma más de dos cucharadas de aceite de oliva al día (incluyendo el usado para freír, el de las comidas fuera de casa, las ensaladas, etc.)?	Si / No
3	¿Toma más de dos raciones de verdura u hortalizas (al menos una de ellas en ensaladas o crudas) al día (las guarniciones o acompañamientos contabilizan como ½ ración)?	Si / No
4	¿Toma más de 3 piezas de fruta (incluyendo zumo natural) al día?	Si / No
5	¿Toma menos de una ración de carnes rojas, hamburguesas, salchichas o embutidos consume al día (una ración equivale a 100-150 gr)?	Si / No
6	¿Toma menos de una porción al día de mantequilla, margarina o nata consume al día (una porción individual equivale a 12 gr)?	Si / No
7	¿Toma menos de una bebidas carbonatadas y/o azucaradas (refrescos, colas, tónicas, bitter) al día?	Si / No
8	¿Bebe 3 o más vasos a la semana de vino?	Si / No
9	¿Toma 3 o más raciones de legumbres consume a la semana (una ración o plato equivale a 150 gr)?	Si / No
10	¿Toma tres o más raciones de pescado o mariscos a la semana (un plato, pieza o ración equivale a 100-150 gr de pescado ó 4-5 piezas de marisco)?	Si / No
11	¿Toma menos de tres piezas de repostería comercial (no casera) como galletas, flanes, dulces o pasteles a la semana?	Si / No
12	¿Toma una o más veces frutos secos a la semana (una ración equivale a 30 gr)?	Si / No
13	¿Consume preferentemente carne de pollo, pavo o conejo en vez de ternera, cerdo, hamburguesas o salchichas (carne de pollo: una pieza o ración equivale a 100-150 gr)?	Si / No
14	¿Toma dos o más veces por semana vegetales cocinados, la pasta, el arroz u otros platos aderezados con una salsa de tomate, ajo, cebolla o puerro elaborada a fuego lento con aceite de oliva (sofrito)?	Si / No

ANEXO 10. Hoja de registro de valoración



A PARTIR DE ESTA SECCIÓN LA INFORMACIÓN SERÁ COMPLETADA POR NOSOTROS. POR FAVOR, INDÍQUENOS QUE HA TERMINADO DE COMPLETAR EL CUESTIONARIO:

1. Talla: _____	2. Peso: _____	3. Dexta: _____
4. Tensión arterial sistólica: _____	5. Tensión arterial diastólica: _____ FC: _____	
6. FIM	9. Chair stand test	
Extensión rodilla derecha: _____	1: _____	
Extensión rodilla izquierda: _____	2: _____	
Flexión bíceps: _____	10. Velocidad marcha 4, 6 y 10 m	
7. Disposición sagital Bipedestación	1. _____	
1. Dorsal: _____ Lumbar: _____ Sacro: _____	2. _____	
2. Dorsal: _____ Lumbar: _____ Sacro: _____	11. Time up and go test	
Disposición sagital Sedestación	1. _____	
1. Dorsal: _____ Lumbar: _____ Sacro: _____	2. _____	
2. Dorsal: _____ Lumbar: _____ Sacro: _____	12. Equilibrio	
8. Dinamometría	Paralelo 1: _____ 2: _____	
Derecha 1: _____ Derecha 2: _____	Semitandem 1: _____ 2: _____	
Izquierda 1: _____ Izquierda 2: _____	Tandem 1: _____ 2: _____	
13. 400 metros		
Tiempo vuelta:		
1 9	16	
2 10	17	FC final: _____
3 11	18	FC media: _____
4 12	19	FC máxima: _____
5 13	20	FC 2 minutos: _____
6 14		
7 15	Tiempo acumulado	
8 16	total: _____	

ANEXO 11. Ficha de percepción del esfuerzo

BIOFIT-Park

Ficha análisis de la percepción del esfuerzo

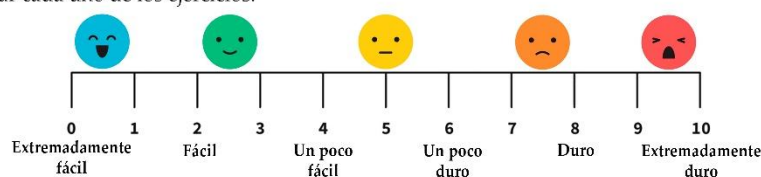
(RTC-2017-6145-1)



Nombre: Código: Fecha: Sesión Número:

En general, ¿Cómo califica el esfuerzo que ha realizado en la sesión de hoy?

En esta ficha debe indicar con un círculo el esfuerzo que ha sentido al realizar cada uno de los ejercicios.



0 significa no sentir ningún esfuerzo.

10 significa que se ha llegado la máximo de nuestra capacidad para continuar.

Percepción del esfuerzo en relación a cada una de las máquinas:

(1). Jinete:

1 2 3 4 5 6 7 8 9 10



(2). Géminis Bajo:

1 2 3 4 5 6 7 8 9 10



(3). Paseo:

1 2 3 4 5 6 7 8 9 10



(4). Fondos:

1 2 3 4 5 6 7 8 9 10



(5). Volantes Círculos:

1 2 3 4 5 6 7 8 9 10



(6). Géminis Alto:

1 2 3 4 5 6 7 8 9 10



(7). Volantes Rotación:

1 2 3 4 5 6 7 8 9 10



(8). C. Gemelos:

1 2 3 4 5 6 7 8 9 10



(9). Surf:

1 2 3 4 5 6 7 8 9 10



(10). Columpio Press:

1 2 3 4 5 6 7 8 9 10



(11). Remo:

1 2 3 4 5 6 7 8 9 10

ANEXO 12. Estudio 1

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Impact of COVID-19 lockdown on health parameters and muscle strength of older women: A longitudinal study

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ABSTRACT

Objectives: The present study aimed to evaluate the effect of a 13-week COVID-19 lockdown on health-related parameters in women aged 60–70 years.**Study design:** Thirty women participated in this longitudinal study. All the assessments were performed before and 13 weeks after the initial phase of the COVID-19 pandemic in Spain (March to June 2020).**Main outcome measures:** A sociodemographic questionnaire was provided, and tests were performed to assess muscle strength, anthropometric measurements, densitometry, blood pressure, blood parameters, Mediterranean diet adherence, and physical activity levels.**Results:** After the lockdown, both healthy and unhealthy lifestyle groups showed a significant worsening of HDL, cholesterol/HDL lipids, and isometric knee extension strength parameters. However, individuals with an unhealthy lifestyle also showed a significant worsening in LDL lipids, Non-HDL lipids, bone mineral density of the femoral neck, fat mass/height (%), truncal fat mass (absolute and percentage), total fat mass (absolute and percentage) and handgrip strength.**Conclusions:** The COVID-19 pandemic had a negative impact on the overall health status of Spanish older women, potentially increasing their susceptibility to comorbidities, such as lipid cholesterol, body fat, and decreased muscle strength.

1. Introduction

The Coronavirus disease (COVID-19) has become the world's leading health news headline. Health authorities in most countries have imposed certain restrictions to prevent the spread of the virus. Unfortunately, these restrictions inevitably disrupted the daily activities of tens of

millions of people, with lockdown becoming a trigger for the deterioration of physical capacity, specially in older population who may have suffered the most from confinement and post-confinement [1].

COVID-19 lockdown could have affected some health parameters, such as level of physical activity and diet, which are risk factors for several cardiovascular and metabolic diseases, such as hypertension,

Abbreviations: BMC, bone mineral content; BMD, bone mineral density; BP, Blood parameters; Chol, total cholesterol; COVID-19, Coronavirus disease; DBP, Diastolic blood pressure; DXA, Dual energy X-ray absorptiometry; FM, Fat mass; GPAQ, Global Physical Activity Questionnaire; HDL, High-Density Lipoprotein cholesterol; ILI, healthy lifestyle; IIG, Handgrip strength; IKE, maximal isometric knee extension strength; IPAQ, International Physical Activity Questionnaire; ISAK, International Society for the Advancement on Kinanthropometry; LDL, Low-Density Lipoprotein cholesterol; MDA, Mediterranean diet adherence; MVPA, moderate to vigorous physical activity; PR, Pulse rate; PREDIMED, prevention with Mediterranean diet; SBP, Systolic blood pressure; Trig, triglycerides; UL, unhealthy lifestyle; WHO, World Health Organization.

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dyslipidaemia and obesity [2–4]. About the reduction of the physical activity, long hours at home may lead to increased sedentary behavior and inactivity, long periods of sitting and lying down; all of which increases the risk of developing or exacerbating chronic diseases [5,6]. Additionally, this isolation resulted in changes in dietary intake of adults and older people that may have increase body fat, accelerated sarcopenia and led to a decline in muscle mass and strength [7].

Most of the longitudinal studies on the effects of lockdown due to COVID-19 have been conducted with young or adult populations, but there are hardly any studies with older people [8]. Therefore, the aim of the present study was to analyze the effects of 13-week of lockdown due to COVID-19, on different health parameters: physical activity level, Mediterranean diet adherence, anthropometric measurements, blood parameters, densitometry parameters, and muscle strength levels of older women.

2. Methods

2.1. Design

This study is a part of the ongoing project (ClinicalTrials.gov Identifier: NCT04958499). Pre-test measurements were taken to begin the intervention specified in this clinical trial. However, this intervention could not be carried out due to COVID-19 pandemic. Instead, the present research was conducted, for which external funding was obtained, with additional permission provided by the institutional ethics committee for it to be carried out. This longitudinal study design followed the Strobe Statement [9].

2.2. Participants

The participants were volunteer woman from the nearby areas of the institution. The sample was collected through announcements in women's centers, senior centers, social centers and health centers in nearby areas. Thirty Spanish women between 60 and 70 years of age participated in the study. The inclusion criteria were: being between 60 and 70 years of age and being female. Participants with smoking, self-reported alcohol dependence, chronic kidney disease, infectious diseases and/or coronary heart disease were excluded from the study. This research could present response bias. Women who came voluntarily to participate in the research could be the most concerned about their health; leaving out of it those women who have a worse lifestyle.

Before the start of the research protocol, all the participants were informed about the experimental protocol (objectives, methods, benefits and risks). All the women underwent assessments before (pre) and after (post) the 13-week period of COVID-19 pandemic isolation (Fig. 1). The pre-tests were performed in February 2020, and the post-tests were performed in June 2020.

Rstudio 3.15.0 software was used to establish the sample size. The significance level was set at $\alpha = 0.05$. According to the standard deviation established for the Femoral neck bone mineral content (BMC) in a previous study [10] and a estimated error of 0.04 g, a valid sample size

of 30 was needed for a confidence interval of 95%.

2.3. Ethics approval and consent to participate

The study obtained approval CE052002 from the Catholic University of Murcia ethics committee on research, in accordance with the Declaration of Helsinki. All patients signed written informed consent forms prior to participating in the study.

2.4. Variables and instruments

The same researchers performed all the measurements in a single session between 8:00 and 14:00 h. The participants were examined barefoot with the temperature of laboratory standardized at 24 °C. Before the test measurement, the participants did not perform warm-up or stretching exercises. There was a 5-minute rest between measurements.

2.4.1. Mediterranean diet adherence

The prevention with mediterranean diet (PREDIMED) questionnaire was used, an instrument for dietary evaluation that provides information on the Mediterranean diet adherence (MDA) of older adults, which was previously validated in the Spanish population [12].

2.4.2. Physical activity level

The Global Physical Activity Questionnaire (GPAQ) is a modified version of the International Physical Activity Questionnaire (IPAQ), and was developed by the World Health Organization (WHO) [13]. This questionnaire classifies participants according to activity level as the main objective of physical activity measurement, and allows for the study of trends and associations with other types of behavior or health outcomes.

2.4.3. Kinanthropometric measurements

Kinanthropometric parameters were measured based on the standards of the International Society for the Advancement on Kinanthropometry (ISAK) [14]. Weight (kg) was evaluated in light clothing without footwear by using an electronic scale (Seca 877, Birmingham, UK), and height (cm) was measured using a stadiometer (Seca 763, Birmingham, UK).

2.4.4. Blood parameters

Blood parameters (BP) were measured following the recommendations for older patients [15]. Systolic blood pressure (SBP), diastolic BP (DBP), and pulse rate (PR) were measured using a calibrated automatic arm device (OMRON, model HEM-7113). The final value for BP, SBP and DBP was the mean of two recordings with three minutes apart.

Finger stick blood samples were collected before 9-h. The Afinion™ Analyzer (Alere, Ltd., Stockport, UK) device was used for the lipid panel test. This test measured total cholesterol (Chol), High-Density Lipoprotein cholesterol (HDL), Low-Density Lipoprotein cholesterol (LDL), Triglycerides (Trig), Non-HDL Lipids (LipidNonHDL) and the Chol/HDL

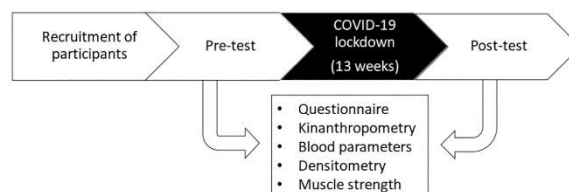


Fig. 1. Experimental design.

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ratio in whole blood, serum and plasma to be used in the diagnosis and treatment of lipid disorders.

2.4.5. Densitometry measurements

Bone mineral content (BMC), bone mineral density (BMD) and body composition were measured with Dual energy X-ray absorptiometry (DXA) (QDR 4500A, fan-beam densitometer, Hologic, Waltham, MA, USA). This method is used for body composition measurements for the evaluation of soft tissue composition, fat mass (FM), lean mass and total mass [16]. The variables measured included: Spine BMC and BMD; Femoral neck BMC and BMD; FM/Height; Lean mass/Height; Total and percentage FM; and Total and percentage trunk FM.

2.4.6. Muscle strength measurement

To measure muscle strength, the participants performed two tests:

Handgrip strength test (HG). HG was measured in a standing position with the arms at the sides. The participants performed one repetition in each hand to familiarize themselves with the device and the test. Each participant was asked to squeeze the grip with maximal strength for 3 s with the right hand. The highest peak strength (kg) recorded between the three attempts was considered for analysis. A digital grip strength dynamometer was used for this (TKK 5401; Takei Scientific Instruments Co., Ltd., Tokyo, Japan).

To determine the maximal isometric knee extension (IKE) strength, the participants were assessed while seated with a knee and hip angle of 90°. Participants seated in a chair were instructed to push as strong as possible for three seconds while provided with verbal encouragement. The extension test was assessed with a force transducer (Musclelab, Ergotest, Norway) sampling at 1000 Hz. The subjects performed three IKE tests with 2 min of rest between tests. The maximum peak force in Newton (Nm) was collected.

2.5. Statistical analysis

The Kolmogorov–Smirnov test and Mauchly's W-test were used to evaluate the normality and the sphericity of the data. The mean and standard deviation were calculated from the quantitative variables, and frequency and percent were used for the qualitative variables. The participants were categorized as having a healthy lifestyle (HL) or unhealthy lifestyle (UL). HL was considered to be those who complied with at least 300 min of moderate to vigorous physical activity (MVPA) (WHO extended recommendation to achieve greater benefits than the recommended 150 min), and who maintained a MDA (above 9 points, calculated according to the mean and median of the sample) vs UL, those who did not comply with either or both parameters. Analysis of covariance (ANCOVA) using to comparing the change from baseline between groups. This analysis was performed unadjusted and adjusted by age as in previous research studies [7]. A two-way ANOVA with repeated measures in 1 factor (time) was used to analyze inter- and intra-group differences. An error of $p \leq 0.05$ was established. The statistical analysis was performed using the statistical package SPSS 21.0 for Windows.

3. Results

A total of 40 women volunteered for the study. Two women were eliminated for not meeting the inclusion and exclusion criteria. Thirty-eight women were included in the study and were measured at pre-test. All of them were contacted to attend the post-test. Three women were infected with Covid at the time of the post-test and 5 women were reluctant to come forward to those detected for fear of contracting Covid. Thirty women attended the post-test and are analyzed in this study.

Table 1 show the characteristics of the sample. The sample consisted of Spanish women between 60 and 70 years old. More than 50% of them were married, retired, and with an educational level corresponding to

Table 1
Characteristic of the sample.

Variable	%(n) or X $\pm$ SD
Age (year old)	64.43 $\pm$ 4.58
Height (cm)	154.15 $\pm$ 7.49
Body mass (kg)	71.27 $\pm$ 12.60
Marital status	
Single	6.67 (2)
Married	56.67 (17)
Separated	6.67 (2)
Widow	30 (9)
Occupation	
Full-Time Worker	13.33 (4)
Part-Time Worker	6.67 (2)
Unemployed	20 (6)
Retired	60 (18)
Education level	
No education	13.33 (4)
Elementary school	56.67 (17)
High school	16.67 (5)
Bachelor's Degrees or higher	13.33 (4)
Living status	
Living with someone	73.33 (22)
Living alone	26.67 (8)
Lifestyle (Active and Mediterranean diet adherence vs non active or no adherence)	
Healthy	30 (9)
Unhealthily	70 (21)

elementary school. Approximately three-quarters of them lived with a partner, and two out of three had an UL.

Table 2 shows that LDL increased ($+10.30 \pm 3.19$; $p = 0.003$), HDL decreased (-7.01 ± 1.78 ; $p = 0.001$), Non-HDL lipids increased ($+8.73 \pm 3.02$; $p = 0.007$), Chol/HDL lipids increased ($+0.42 \pm 0.08$; $p < 0.001$), femoral neck BMD decreased (-0.02 ± 0.01 ; $p = 0.017$), percent FM/height increased ($+0.37 \pm 0.10$; $p = 0.002$), total FM (kg) increased ($+0.81 \pm 0.24$; $p = 0.002$), percent FM (%) increased ($+0.67 \pm 0.21$; $p = 0.003$), total trunk FM (kg) increased ($+0.53 \pm 0.20$; $p = 0.013$), percentage trunk FM (%) increased ($+1.06 \pm 0.33$; $p = 0.003$), HG decreased (-0.87 ± 0.36 ; $p = 0.023$) and IKE decreased (-302.80 ± 24.14 ; $p < 0.001$) after the lockdown, significantly. When these changes were adjusted by age values are maintained.

Table 3 shows the changes before and after lockdown according to HL and UL. The HL group showed a decrease in HDL (-6.85 ± 3.04 ; $p = 0.033$), increase in Chol/HDL lipids (0.29 ± 0.11 ; $p = 0.012$), increase trunk FM (1.16 ± 0.51 ; $p = 0.032$) and decrease in IKE (-303.06 ± 41.90 ; $p < 0.001$), significantly. The UL group showed an increased BMI (0.41 ± 0.16 ; $p = 0.015$), and increased LDL ($+13.76 \pm 3.33$; $p < 0.001$), decreased HDL (-6.91 ± 1.87 ; $p = 0.001$), increased Non-HDL lipids ($+14.15 \pm 3.02$; $p < 0.001$), increased Chol/HDL lipids ($+0.51 \pm 0.07$; $p < 0.001$), decreased femoral neck BMD (-0.02 ± 0.01 ; $p = 0.009$), increased FM/height (%) ($+0.46 \pm 0.11$; $p < 0.001$), increased trunk FM (kg) ($+0.52 \pm 0.22$; $p = 0.024$), increased trunk FM (%) ($+1.04 \pm 0.32$; $p = 0.003$), increased total FM (kg) ($+1.05 \pm 0.26$; $p < 0.001$), increased total FM (%) ($+0.87 \pm 0.21$; $p < 0.001$), decreased HG (-0.80 ± 0.38 ; $p = 0.046$) and decreased IKE (-304.29 ± 25.75 ; $p < 0.001$), significantly. No differences were observed between groups in the pre-post lockdown change.

4. Discussion

The main objective of this study was to analyze the effects of 13-week period of lockdown due to COVID-19 on different health parameters:

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Table 2
Effect of lockdown due to Covid pandemic (Unadjusted and adjusted by age).

Variable	Unadjusted			p	95% CI (Mpost-Mpre)	Adjusted by age		
	Pre test (M ± SD)	Post test (M ± SD)	Difference post pre (M ± SD)			Difference post pre (M ± SD)	p	95% CI (Mpost-Mpre)
BMI (kg/m ²)	29.97 ± 4.54	30.25 ± 4.67	0.28 ± 0.16	0.097	-0.05;0.61	0.26 ± 0.15	0.097	-0.05;0.56
BP (mmHg)	97.43 ± 11.16	95.5 ± 11.29	-1.89 ± 2.22	0.403	-6.43;2.67	-2.00 ± 2.24	0.38	-6.59;2.6
SBP (mmHg)	132.37 ± 21.61	130.03 ± 19.89	-2.46 ± 4.84	0.616	-12.40;7.48	-2.70 ± 4.89	0.585	-12.74;7.34
DBP (mmHg)	79.97 ± 10.13	78.23 ± 10.79	-1.60 ± 1.62	0.332	-4.2;1.72	-1.64 ± 1.65	0.327	-5.03;1.74
PR (bpm)	68.87 ± 11.63	66.03 ± 11.24	-2.52 ± 1.52	0.11	-5.64;0.61	-2.48 ± 1.55	0.121	-5.67;0.7
Chol (mg/dL)	190.1 ± 29.44	195.7 ± 24.53	1.73 ± 3.99	0.669	-6.47;9.92	1.50 ± 4.01	0.712	-6.75;9.75
LDL (mg/dL)	101.79 ± 25.82	114.13 ± 20.42	10.30 ± 3.19	0.003	3.76;16.84	10.07 ± 3.17	0.004	3.55;16.58
HDL (mg/dL)	66.17 ± 12.61	60.27 ± 12.96	-7.01 ± 1.78	0.001	-10.67;3.35	-6.88 ± 1.78	0.001	-10.54;3.23
Trig (mg/dL)	110.72 ± 58.83	106.3 ± 41.82	-8.30 ± 10.95	0.455	-30.75;14.16	-8.93 ± 10.99	0.424	-31.53;13.66
LipidNonHDL (mg/dL)	123.93 ± 24.01	135.43 ± 20.09	8.73 ± 3.02	0.007	2.55;14.92	8.38 ± 2.87	0.007	2.48;14.28
Chol/HDL (mg/dL)	2.92 ± 0.49	3.35 ± 0.59	0.42 ± 0.08	<0.001	0.26;0.57	0.40 ± 0.06	<0.001	0.27;0.53
Spine BMC (kg)	1.82 ± 0.27	1.83 ± 0.26	2.95 ± 9.71	0.763	-16.97;22.88	2.55 ± 9.83	0.798	-17.66;22.76
Spine BMD (g/cm ²)	1.03 ± 0.08	1.03 ± 0.09	-0.00 ± 0.00	0.756	-0.01;0.01	-0.00 ± 0.00	0.796	-0.01;0.01
Femoral neck BMC (g)	3.14 ± 0.78	3.15 ± 0.79	0.02 ± 0.03	0.634	-0.05;0.08	0.02 ± 0.03	0.612	-0.05;0.08
Femoral neck BMD (g/cm ²)	0.7 ± 0.1	0.69 ± 0.11	-0.02 ± 0.01	0.017	-0.03;0.00	-0.02 ± 0.01	0.02	-0.03;0.00
FM/Height (%)	13.71 ± 3.34	14.1 ± 3.4	0.37 ± 0.10	0.002	0.15;0.58	0.36 ± 0.11	0.002	0.15;0.58
Lean mass/Height (kg/m ²)	14.84 ± 1.42	14.81 ± 1.5	-0.02 ± 0.10	0.817	-0.24;0.19	-0.05 ± 0.08	0.58	-0.21;0.12
Trunk FM (kg)	16.09 ± 4.15	16.59 ± 4.15	0.53 ± 0.20	0.013	0.12;0.95	0.54 ± 0.21	0.015	0.11;0.96
Trunk FM (%)	46.2 ± 4.95	47.23 ± 4.52	1.06 ± 0.33	0.003	0.38;1.73	1.10 ± 0.30	0.001	0.49;1.72
Total FM (kg)	32.66 ± 8.70	33.54 ± 8.78	0.81 ± 0.24	0.002	0.32;1.31	0.81 ± 0.25	0.003	0.30;1.31
Total FM (%)	46.24 ± 4.43	46.98 ± 4.25	0.67 ± 0.21	0.003	0.25;1.09	0.69 ± 0.20	0.002	0.29;1.1
HG (kg)	23.56 ± 5.68	22.78 ± 5.13	-0.87 ± 0.36	0.023	-1.60;0.13	-0.85 ± 0.36	0.027	-1.6;0.11
IKE (Nm)	548.02 ± 167.46	248 ± 68.91	-302.80 ± 24.14	<0.001	-352.34; 253.26	-303.67 ± 24.50	<0.001	-354.03; 253.32

Abbreviations: BMI = body mass index; BMC = bone mineral content; BMD = bone mineral density; BP = blood pressure; bpm = beats per minute; DBP = diastolic blood pressure; FM = fat mass; HDL = high density lipoprotein; IIG = I-handgrip; IKE = Isometric knee extension strength; LDL = low density lipoprotein; MBP = mean blood pressure; mmHg = millimeters of mercury; Nm = newton meter; PR = pulse rate; SBP = systolic blood pressure; Chol = total cholesterol; Trig = triglycerides.

physical activity level, Mediterranean diet adherence, anthropometric measurements, blood parameters, densitometry parameters and muscle strength levels of women aged 60–70 years. The results showed that blood HDL, LDL and Non-HDL lipid values worsened after lockdown, with a significant increase in LDL and a decrease in HDL, as in previous studies [17]. In addition, in the present study, a significant worsening of HDL and cholesterol/HDL lipid values was observed in individuals who had a HL and UL due to the lockdown, but those who had an UL also presented a worsening LDL, and Non-HDL lipid values. Therefore, maintaining a healthy lifestyle during the lockdown period, including physical activity and a healthy diet, could decrease the negative effects of habit changes on blood parameters during lockdown [17,18]. These changes in daily life may increase the risk of developing heart disease in the long term [18], with this being especially relevant in the population of the present investigation as they are adult and older women; thus, age should be taken into consideration as it increases the predisposition to cardiovascular disease [19].

Regarding blood pressure, SBP significantly increased with age. This may pose a risk, as a high SBP associated with age has been associated to the possible occurrence of major cardiovascular disease events, coronary heart disease, stroke, and heart failure in other studies [24]. In contrast, no significant changes were found in SBP, DBP or BP pre and post lockdown. Furthermore, differences were not found between HL and UL. The lack of changes may be due to the average time period elapsed [25].

The present investigation also found a significant increase in trunk FM (absolute and percentage), total FM (absolute and percentage), and FM/height percentage after lockdown, in line with previous studies [26]. Considering that in the adult and older population, height does not

usually change in the short term [27], the increase in FM/height percentage could be due to the changes found in FM. Previous studies have shown that lockdown led to a decrease in the level of physical activity or a worsening of eating habits, including a higher frequency of snacking, with these factors affecting the female gender to a greater extent [28]. Not surprisingly, in the present study, it was found that those with an UL were women who showed the greatest significant increase in the variables related to total and trunk fat accumulation and increased significantly in BMI as well. Another possible explanation could be that there was an increase in total FM and trunk FM with age [29]. The area of fat mass distribution is a factor to consider, as total FM has been correlated with different levels of cardiometabolic risk, as well as trunk FM, which is associated with a high risk of cardiovascular disease [29]. Therefore, in light of the results of the present study, older women who have an UL would have a higher probability of suffering from this type of pathologies.

Regarding bone mass, in general no differences were found when comparing the pre-post lockdown variables. However, when dividing the women according to their lifestyle, a significant decrease in femoral neck BMD was found in those with an UL. These changes in normal (non-lockdown) situations may be due to multiple reasons, including genetics, some types of medication, other diseases, nutrition and lifestyle [30]. With respect to the latter, it is worth noting that lifestyle was one of the most affected factors during the lockdown [23]. The first cause may be physical inactivity and a sedentary lifestyle [31]. Disuse or prolonged periods of inactivity such as lockdown or the absence of stimulus on the skeleton, favor the reduction of bone mass, making it more fragile, while subjecting it to a mechanical load through exercise increases bone mass

Table 3
Effects of lockdown according to healthy or unhealthy lifestyle + Time*Group Interaction (all age-adjusted).

Variable		Pre test (M ± SD)	Post test (M ± SD)	Adjusted by age			Group * time interaction	
				Difference post pre (M ± SD)	p	95% CI (Mpost Mpre)	F	Sig
BMI (kg/m ²)	HL	30.65 ± 4.64	30.73 ± 4.96	0.11 ± 0.26	0.682	-0.42;0.63	1.008	0.328
	UL	29.67 ± 4.57	30.05 ± 4.65	0.41 ± 0.16	0.015	0.09;0.73		
BP (mmHg)	HL	96.22 ± 13.8	96.63 ± 12.82	-1.19 ± 3.83	0.758	-9.06;6.67	0.127	0.724
	UL	97.95 ± 10.17	95.02 ± 10.88	-2.8 ± 2.35	0.244	-7.63;2.03		
SBP (mmHg)	HL	129.78 ± 20.3	130.56 ± 16.71	-2.03 ± 8.36	0.81	-19.21;15.15	0.018	0.893
	UL	133.48 ± 22.55	129.81 ± 21.49	-3.37 ± 5.14	0.518	-13.93;7.19		
DBP (mmHg)	HL	79.44 ± 15.38	79.67 ± 16.02	-0.77 ± 2.81	0.786	-6.56;5.01	0.276	0.604
	UL	80.19 ± 7.35	77.62 ± 8.05	-2.52 ± 1.73	0.158	-6.07;1.04		
PR (bpm)	HL	68.56 ± 10.42	65.89 ± 8.96	-2.03 ± 2.65	0.451	-7.47;3.42	0.086	0.772
	UL	69 ± 12.35	66.1 ± 12.28	-2.94 ± 1.63	0.082	-6.29;0.41		
Chol (mg/dL)	HL	198.88 ± 33.69	200.33 ± 26.39	-4.24 ± 6.87	0.542	-18.35;9.87	2.013	0.168
	UL	186.76 ± 27.81	193.71 ± 24.09	7.23 ± 4.22	0.098	-1.44;15.91		
LDL (mg/dL)	HL	105.12 ± 26.43	114.44 ± 16.44	6.37 ± 5.42	0.251	-4.78;17.52	1.34	0.258
	UL	100.52 ± 26.13	114 ± 22.28	13.76 ± 3.33	<0.001	6.91;20.62		
HDL (mg/dL)	HL	72.13 ± 15.39	67.56 ± 17.71	-6.85 ± 3.04	0.033	-13.11;0.60	0.000	0.987
	UL	63.9 ± 10.95	57.14 ± 9.16	-6.91 ± 1.87	0.001	-10.76;3.07		
Trig (mg/dL)	HL	108.25 ± 54.67	90.78 ± 29	-19.94 ± 18.8	0.299	-58.59;18.70	0.988	0.329
	UL	111.67 ± 61.61	112.95 ± 45.22	2.07 ± 11.55	0.859	-21.68;25.82		
LipidNonHDL (mg/dL)	HL	126.75 ± 25.68	132.78 ± 18.55	2.61 ± 4.91	0.599	-7.48;12.71	3.976	0.057
	UL	122.86 ± 23.91	136.57 ± 21.04	14.15 ± 3.02	<0.001	7.95;20.35		
Chol /HDL (mg/dL)	HL	2.81 ± 0.51	3.1 ± 0.67	0.29 ± 0.11	0.012	0.07;0.52	2.913	0.1
	UL	2.96 ± 0.49	3.46 ± 0.53	0.51 ± 0.07	<0.001	0.38;0.65		
Spine BMC (kg)	HL	1.82 ± 0.25	1.82 ± 0.24	-4.43 ± 16.82	0.794	-39.00;30.14	0.496	0.488
	UL	1.82 ± 0.28	1.83 ± 0.28	9.53 ± 10.34	0.365	-11.72;30.77		
Spine BMD (g/cm ²)	HL	1.03 ± 0.09	1.02 ± 0.09	-0.00 ± 0.01	0.934	-0.02;0.01	0.013	0.909
	UL	1.03 ± 0.08	1.03 ± 0.09	-0.00 ± 0.00	0.722	-0.01;0.01		
Femoral neck BMC (g)	HL	3.21 ± 0.56	3.19 ± 0.57	0.01 ± 0.05	0.851	-0.10;0.12	0.036	0.852
	UL	3.11 ± 0.87	3.13 ± 0.88	0.02 ± 0.03	0.599	-0.05;0.09		
Femoral neck BMD (g/cm ²)	HL	0.7 ± 0.08	0.69 ± 0.1	-0.01 ± 0.01	0.252	-0.03;0.01	0.219	0.644
	UL	0.7 ± 0.11	0.68 ± 0.11	-0.02 ± 0.01	0.009	-0.03;0.01		
FM/Height (%)	HL	14.24 ± 3.21	14.48 ± 3.57	0.27 ± 0.18	0.152	-0.10;0.64	0.816	0.375
	UL	13.49 ± 3.45	13.94 ± 3.4	0.46 ± 0.11	<0.001	0.23;0.69		
Lean mass/Height (kg/m ²)	HL	14.94 ± 1.63	14.9 ± 1.72	-0.09 ± 0.14	0.506	-0.38;0.19	0.346	0.561
	UL	14.8 ± 1.36	14.78 ± 1.44	0.00 ± 0.09	0.976	-0.17;0.18		
Trunk FM (kg)	HL	16.59 ± 4.66	17.05 ± 5.44	0.55 ± 0.35	0.127	-0.17;1.27	0.007	0.934
	UL	15.87 ± 4.02	16.39 ± 3.62	0.52 ± 0.22	0.024	0.08;0.96		
Trunk FM (%)	HL	47.07 ± 3.47	47.93 ± 4.41	1.16 ± 0.51	0.032	0.11;2.22	0.039	0.844
	UL	45.82 ± 5.5	46.92 ± 4.64	1.04 ± 0.32	0.003	0.39;1.69		
Total FM (kg)	HL	33.91 ± 9.99	34.39 ± 10.58	0.56 ± 0.42	0.196	-0.31;1.42	0.998	0.327
	UL	32.13 ± 8.31	33.17 ± 8.15	1.05 ± 0.26	<0.001	0.52;1.59		
Total FM (%)	HL	47.14 ± 3.81	47.52 ± 4.34	0.51 ± 0.34	0.139	-0.18;1.21	0.806	0.378
	UL	45.85 ± 4.71	46.75 ± 4.3	0.87 ± 0.21	<0.001	0.45;1.30		
HG (kg)	HL	23.12 ± 5.36	22.35 ± 5.73	-0.91 ± 0.62	0.157	-2.18;0.37	0.021	0.886
	UL	23.75 ± 5.92	22.97 ± 4.99	-0.80 ± 0.38	0.046	-1.59;0.02		
IKE (Nm)	HL	534.05 ± 148.7	246.51 ± 64.51	-303.06 ± 41.90	<0.001	-389.19;216.93	0.001	0.98
	UL	554.01 ± 178.02	248.64 ± 72.25	-304.29 ± 25.75	<0.001	-357.23;251.36		

Abbreviations: BMC = bone mineral content; BMD = bone mineral density; BMI = body mass index; BP = blood pressure; bpm = beats per minute; DBP = diastolic blood pressure; FM = fat mass; HDL = high density lipoprotein; HG = Handgrip; HL = healthy lifestyle; IKE = Isometric knee extension strength; LDL = low density lipoprotein; MBP = mean blood pressure; mmHg = millimeters of mercury; Nm = newton meter; PR = pulse rate; SBP = systolic blood pressure; Chol = total cholesterol; Trig = triglycerides; UL = unhealthy lifestyle.

[31]. On the other hand, home lockdown reduced exposure to the sun over a long period of time [31], thus affecting vitamin D synthesis, and therefore negatively affecting calcium absorption in the intestine, the maintenance of adequate levels of calcium and phosphate for optimal bone formation, and the promotion of proper functioning of the parathyroid hormone, which maintains serum calcium levels [31]. For these reasons, the sum of these factors may have been the main cause for the reduced BMD observed in the population with an UL.

Another objective of this study was to test the effects of lockdown on muscle strength production capacity. We found a significant worsening of the results obtained in the IKE test by both groups after the lockdown. These results are in agreement with those expected, due to the effect of age on the decrease in the capacity to produce strength [21], in addition to a situation of restricted mobility and, therefore, a decrease in physical activity [32]. On the other hand, only the UL older women showed a significantly worsening HG test results. This may be due to the maintenance of the active lifestyle by the HL older women, whereas the UL older women were able to greatly reduce their daily physical activity

during the lockdown than post lockdown due to the restrictive mobility policies. This may be because the muscle response to inactivity is stronger than to physical activity [32]. The loss of muscle strength, in addition to the absence of significant differences in the Lean mass/Height variable, reinforces the idea found in previous research, where it was observed that the magnitude of strength loss observed due to aging and inactivity was greater than the degree of muscle mass loss [32]. Therefore, it could be said that age, inactivity, and an UL during lockdown, promoted the loss of muscle strength in the population studied.

The main strength of the present research was the combined study of physical, lifestyle and physiological parameters during this period, with a longitudinal study which included a field test to analyze the effects of lockdown on the health of older women. Therefore, the data collected in the present study could be very useful in similar, future situations to predict the changes in health variables in this population group, as well as to improve the health management system by political entities. On the other hand, more research will be necessary, especially in the most affected or at-risk groups, in this case on their health in relation to

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physical activity and lifestyle. Regarding the limitations encountered, the post-lockdown measurements could not be performed until the mobility restrictions imposed allowed the sample to access the center where tests were performed, as well as the absence of a control group that was not in lockdown.

As conclusion, it was observed that lockdown had a great negative impact on Spanish older women in most of the measured parameters: cholesterol, femoral neck BMD, FM and strength values. In addition, it was found that a HL could be a protective factor against the age-associated increase in LDL, decrease in HDL, increase in FM, and decrease strength values. These results should be taken into account due to the potentially large negative impact on public health that a situation of lockdown and social isolation such as the one experienced could have, so that non-pharmacological strategies such as physical exercise and a healthy diet are deemed necessary to ensure the health of individuals during possible future lockdown situations. Furthermore, it is crucial to highlight the need for future studies investigating not only the impact of COVID-19 lockdown restrictions on health and muscle strength parameters, but also the short- and long-term effects of specific interventions that aim to improve overall health and include a home-tailored physical exercise program.

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Declaration of competing interest

The authors declare that they have no competing interests.

Data availability

Data will be made available on request.

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ANEXO 13. Estudio 2



Sagittal spine disposition and pelvic tilt during outdoor fitness equipment use and their associations with kinanthropometry proportions in middle-aged and older adults

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ABSTRACT

Background. Outdoor fitness training has become popular as a tool for improving the health, especially middle-aged and older adults. For this purpose, outdoor fitness equipment (OFE) have been installed in public areas. However, their safety and effectiveness are still unknown. The aim of the present research was to analyze the sagittal disposition of the spine and pelvic tilt during the use of OFE, and to determine the influence of anthropometric variables on these factors in middle-aged and older adults.

Methods. Seventy healthy volunteers, 56 women and 14 men (age: 63.14 ± 8.19 years) participated in the study. Sagittal spine disposition and pelvic tilt were measured using a Spinal Mouse®, in the relaxed standing position, and during the use of the OFE. In addition, kinanthropometry variables were also measured according to the guidelines of the International Society for the Advancement of Kinanthropometry.

Results. Regarding thoracic kyphosis, a significant decrease was found in thoracic kyphosis in the initial position (IP) in single bonny rider (SBR) ($p = 0.006$) and row ($p = 0.046$), and a significant increase in the final position (FP) in the row ($p = 0.011$), surfboard ($p < 0.001$) and air walker ($p = 0.027$) machines. In relation to the lumbar curvature and pelvic tilt, a significant decrease in lumbar lordosis and a decrease in pelvic anteversion were observed in the IP and FP in SBR and row; and in the bike ($p < 0.001$) machine. In the surfboard machine, a significant decrease in lumbar lordosis was found ($p = 0.002$), with no changes in pelvic tilt. According to the multiple linear regression analysis, the subjects with a higher cormic index and height were more at risk of increasing their thoracic kyphosis, decreasing lumbar lordosis and/or decreasing pelvic anteversion towards pelvic retroversion.

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Conclusions. Middle-aged and older adults show spinal misalignments when using the OFE with respect to the standing position, showing a decrease in the thoracic kyphosis in IP of SBR and ROW, and a significant increase in the surfboard and air walker, and in the FP of Row, in the lumbar lordosis in all the OFE in sitting and some in standing, and in the pelvic anteversion in all the OFE in sitting. The variables height and the cormic index explained most of the changes in sagittal spine disposition.

Subjects Anatomy and Physiology, Geriatrics, Kinesiology, Orthopedics, Biomechanics

Keywords Ergonomic, Spinal curvature, Posture, Public facility, Sports and recreational facilities, Sports equipment

INTRODUCTION

Ergonomics is understood as the part of biomechanics that works on the adaptation of machinery and workplaces to optimize them for the safety and efficiency of users (Georgoulas, Linner & Bock, 2014; Signorile et al., 2017). For this purpose, machines and furniture are adapted to the body proportions of the subjects for whom they are destined (Castellucci et al., 2015; Colvin, Flores & Hardi, 2013). Among these machines, we find the ones used for guided bodybuilding exercises, which are very common in fitness centers (Cardozo et al., 2019; Ribeiro, Nunes & Schoenfeld, 2020; Signorile et al., 2017). These strength training machines are designed to be effective and safe for users (Chow, 2013; Chow & Wu, 2019; Coratella et al., 2020). In this way, the machinery is designed so that during sports practice the position of the body is optimal for the desired muscular action, without causing alterations in the rest of the body structures or in the work itself (Coratella et al., 2020; Maffiuletti & Lepers, 2003; Rodriguez-Ridao et al., 2020).

A lack of ergonomics or improper use of weight training machines during training can be detrimental to the health of the person performing the exercise, and can also cause changes in the maximum strength-producing capacity of the user by modifying biomechanics. More specifically, the execution of exercises with an excessive range of motion and the adoption of inadequate postures, especially with regard to the spine, or an incorrect execution of the exercise performed (Chow, 2013; Rodriguez-Ridao et al., 2020), together with an increase in the loads during execution can lead to multiple injuries of different kinds (Hartmann, Wirth & Klusemann, 2013; McGill, Cannon & Andersen, 2014; Sayers et al., 2020). Among the most frequent injuries that could result from overloading caused by incorrect use of this type of machinery we find herniated discs, spondylolysis, and spondylolisthesis (Harrison et al., 2005). However, the origin of injuries and pathologies of both the spine and the adjacent muscular system is multifactorial, so other factors such as technique, fatigue, sarcopenia or age must also be taken into consideration (Gottschlich & Young, 2011; Montero-Fernandez & Serra-Rexach, 2013; Ohyama et al., 2019).

To avoid these situations of lack of ergonomics or improper use of weight training machines during training, as well as the most frequent related injuries (Ailon et al., 2015; Harrison et al., 2005), the vast majority of weight training machines on the market today are adjustable. In this way, they can be adapted to each user, regardless of their anthropometric

characteristics and proportions, while maintaining efficiency and safety when training with them. In addition, as they are mostly guided machines, the muscles involved can be worked in a controlled range of motion (Ribeiro, Nunes & Schoenfeld, 2020), which reduces the risk of compensations in other structures. This type of compensation occurs especially in frail subjects with postural deviations or previous spinal injuries, as is the case in middle-aged and older adults (Ribeiro, Nunes & Schoenfeld, 2020). More specifically, previous studies have found that the older population tends to show thoracic hyperkyphosis, reductions in lumbar curvature and intervertebral disc degeneration (Ailon et al., 2015; Ohyama et al., 2019). Recent systematic reviews (Bayattork et al., 2020) and systematic reviews with meta-analysis (Gonzalez-Galvez, Gea-Garcia & Marcos-Pardo, 2019) have proven that systematic strength training can lead to improvement in the sagittal spinal curvatures, or correct malalignments, therefore, it would be a highly recommended training in this population (Ohyama et al., 2019; Toprak-Çelenay & Özer Kaya, 2017).

Despite this evidence, most studies that have analyzed the adaptations that occur in the sagittal spine disposition with the systematic practice of exercise have focused on specific sports in athletes of different categories (Grabara, 2018; López-Miñarro et al., 2017) or certain types of physical exercise in older (Grabara & Szopa, 2015). However, few studies have analyzed the acute influence of physical exercise on the sagittal spine disposition during the use of specific sports equipment. More specifically, the sagittal spine disposition has been analyzed in kayakers or canoeists who were paddling in the boat (Abelleira-Lamela et al., 2020; López-Miñarro, Muyor & Alacid, 2012), or in cyclists when they were standing on the bike (Muyor, 2015; Muyor, López-Miñarro & Alacid, 2011). However, there are no studies that have analyzed the adaptations that occur in the sagittal spine disposition during the use of sports fitness equipment such as gym equipment.

Due to the benefits observed from training with weight training machines such as strength and functional fitness gains, as well as increase in hormones of bone formation in those who use them, especially in older adults (Cardozo et al., 2019; Moghadasi & Siavashpour, 2013), the installation and use of outdoor fitness equipment (OFE) areas as a tool for the improvement of the health of the population, especially middle-aged and older adults, has been popularized by different governmental institutions (Cohen et al., 2012). OFE are outdoor sports facilities commonly located in public places, composed of machines that seek to have a certain similarity with the weight training machines found in indoor sports centers. However, this type of equipment, unlike the equipment used in fitness rooms, is not adjustable, and no studies have been found that have analyzed the sagittal disposition of the spine when using this type of machinery, or the influence that anthropometric proportions could have on them. Therefore, the aim of the present research was to analyze the sagittal disposition of the spine and pelvic tilt during the use of OFE, as well as to determine the influence of anthropometric variables on these factors in middle-aged and older adults. It was hypothesized that there would be changes in sagittal spine disposition and pelvic tilt during the use of OFE and that these changes would depend on anthropometric parameters related to structural bone characteristics in middle-aged and elderly adults.

MATERIALS & METHODS

Participants

The data used in this cross-sectional study derives from the Intelligent Outdoor Fitness Equipment Project (Design and manufacture of new ergonomic, efficient and healthy outdoor fitness equipment with an application for mobile devices (APP) to assess and control training); code: RTC-2017-6145-1, 2017; with a research grant from the Spanish Ministry of Science, Innovation and Universities.

The sample consisted of 70 healthy volunteers, 56 women and 14 men aged from 50 to 80 years old (mean age: 63.14 ± 8.19 years). The inclusion criteria were: (1) minimum age of 50 years and maximum age of 85 years; (2) functional independence; (3) not being part in a training program during the measurements; (4) not to have any pathology that would prevent the performance of the tests; (5) not having had an operation on the spine or hamstring musculature; and (6) not present a medically diagnosed structural spinal pathology such as a structured thoracic hyperkyphosis, a structured lumbar hyperlordosis, or some kind of structured rectification, etc.

The sample size and power were established taking into account the standard deviation (6.67) of the thoracic curvature variable in a sample with similar characteristics ($n = 42$) (Hasegawa et al., 2018). The sample size of this study was 70 subjects, with a power of 95% and a significance level of 0.05; an estimated error of 1.56° was found. Rstudio 3.15.0 software was used to determine the sample size.

The study was conducted in accordance with the Declaration of Helsinki, and was approved by the institutional ethical committee of the Catholic University of Murcia (Ethical Application Ref: CE111908). This study was designed following the Strobe Statement (Von Elm et al., 2008). All participants were informed about the tests to be performed in this study, and signed an informed consent form before the measurements.

Measurements

The same trained researcher measured the participants in a single session between 09:00 and 11:00 h. The laboratory temperature was standardized at 24°C . The participants were instructed to wear lightweight clothes. Participants had not previously exercised on the same day of the assessment and at least two hours had passed since they had been in the supine position (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015).

Sagittal spine disposition and pelvic tilt

The sagittal spine disposition and pelvic tilt were measured using the Spinal Mouse® system (Idiag, Fehraltorf, Switzerland). Measurements were taken randomly in the relaxed standing position, and using the OFE. In the OFE with a cyclic movement, the measurements were taken at the starting position, defining this as the position when the participant was on the OFE, but before starting the movement for which it is intended. In the acyclic OFE, the measurement was made in the same conditions as the cyclic ones, considering this position as the initial position (IP). After that, the subject was asked to execute the movement for which the OFE was designed at a controlled speed until reaching the end of the concentric phase in the OFE. The participant had to maintain this final



Figure 1 Outdoor fitness equipment.

Full-size [DOI: 10.7717/peerj.12657/fig-1](https://doi.org/10.7717/peerj.12657/fig-1)

position (FP) for the sagittal spine disposition to be assessed. Since, the way OFE is used could influence the disposition in it (Chow & Wu, 2019), in the present investigation each OFE was used according to the manufacturer's recommendations. More specifically, in the air walker the participant did a reverse stride, standing facing forward on the OFE, grasping the front; in the Bike the participant was sitting on the OFE, with one foot on each pedal, hands on the handgrip and crank parallel to the ground; in the surfboard the participant was standing on the platform grasping both sides; in the SBR the participant also was sitting on the seat, with feet on the support, and grasping the handgrip with hand supine, pull with arms to 90° elbow flexion; and in the Row the participant was sitting on the seat, grasping the handgrip with hands about shoulder width apart, and feet on the supports, pull on the handgrip to 90° elbow flexion. The outdoor fitness pieces of equipment were obtained from the company Entorno Urbano S.L.U (Murcia, Spain) (Fig. 1).

Each position was performed twice, and the final value of each measurement was the mean of both measurements. Five minutes were left between the different positions to avoid acute adaptations to the maintenance of a given position in an isometric manner following the methodology of previous studies (López-Miñarro et al., 2017). For thoracic and lumbar curvatures, a positive value indicated that the curve was kyphotic, while a negative value indicated that the curve was lordotic. For pelvic tilt, a positive value indicated that the

presence of pelvic anteversion, while a negative value indicated the presence of pelvic retroversion.

Kinanthropometry

The measurements were taken according to the guidelines of the International Society for the Advancement of Kinanthropometry (*Esparza-Ros, Vaquero-Cristóbal & Marfell-Jones, 2019*) by an accredited anthropometrist. The measurements taken were body mass, stretch stature, sitting height, waist and hip girths, arm and forearm length, and biacromial and biiliocrystal breaths. A Tanita BC-545N scale (Tanita, Arlington Heights, Illinois, USA) was used to measure body mass, and a HR001 portable stadiometer (Tanita, Arlington Heights, Illinois, USA) was used to measure stretch stature and sitting height. The lengths were taken with a Pro model segmometer (Cescorf Ltd., Porto Alegre, Brazil), and breaths with a large sliding caliper (Cescorf Ltd., Porto Alegre, Brazil). Each measurement was taken twice or three times if the difference between the first two measurements was greater than 1%, taking the mean or median, respectively. With the measurements taken, the BMI ($\text{weight}/(\text{Height}(\text{m})^2)$), cormic index ($((\text{sitting height}/\text{height}) \times 100)$), waist-hip ratio (Waist girths/Hip girths); cormic index; upper limb length (arm length + forearm length) and acromio-iliac index ($((\text{biiliac diameter}/\text{biacromial diameter}) \times 100)$) were calculated as previously described in *Salces et al. (2007)*.

Statistical analyses

The Kolmogorov–Smirnov test and Mauchly's W-test were used to evaluate the normality and the sphericity of the data. The mean and standard deviation were calculated, and to determine differences between each curvature in standing position and in each OFE, a *t*-test for correlated samples was used. The effect size was calculated by Cohen's *d* coefficient. For this purpose, a value > 0.8 was considered a high effect; a value between 0.6 and 0.8 was considered a moderate-high effect; a value between 0.4 and 0.6 was considered a moderate effect; a value between 0.2 and 0.4 was considered a low-moderate effect; and a value < 0.2 was considered a low effect size (*Cohen, 1988*). An ANCOVA was performed to analyze the influence of sex and height in the comparison of the differences between the position in standing and in the OFE. The effect size was calculated with partial eta squared (η_p^2). To determine the association between sagittal spine disposition and pelvic tilt during OFE use and kinanthropometry proportions Pearson's bivariate correlation coefficients were used. The established ranges of correlation were as follows: $r > 0.7$ for a high correlation, 0.5–0.7 for a moderate correlation, and < 0.5 for a low correlation. Stepwise multiple linear regression models were used to predict sagittal spine disposition according to kinanthropometry proportions. In case of a nonlinear multiple regression model provided a best explanation of the variance that the multiple linear regression models, the best model association between the dependent and independent variables was explored with a curvilinear estimation. The statistical significance was set at $p < 0.05$. The statistical analyses were carried out using SPSS (Version 22, SPSS Inc., Chicago, IL, USA).

RESULTS

Table 1 show the mean and standard deviation of the middle-aged and older adults in anthropometric basic measures, BMI, girths, lengths, breadths and proportionality variables, as well as the sagittal spine disposition in standing position, and during the use of the OFE. It was found that the sample presented normal BMI and waist-hip ratio values ($29.69 \pm 4.27 \text{ kg/m}^2$ and 0.90 ± 0.09 , respectively). With respect to the spine disposition, the thoracic curvature in standing position was $50.10 \pm 10.67^\circ$, the lumbar curvature was $-31.85 \pm 9.34^\circ$, and the pelvic tilt was $21.32 \pm 7.31^\circ$. In the OFE, thoracic curvatures were between $46.92 \pm 11.51^\circ$ to $53.79 \pm 10.59^\circ$; lumbar curvatures were between $-31.23 \pm 10.20^\circ$ to $4.82 \pm 9.47^\circ$; and pelvic tilt were between $-4.25 \pm 9.59^\circ$ to $22.42 \pm 8.39^\circ$. The differences in the sagittal spine disposition and pelvic tilt between the different OFE and the standing position is shown in the Table 2. Regarding thoracic kyphosis, a significant decrease was found in the IP in SBR ($p = 0.006$) and row ($p = 0.046$), and a significant increase in the FP in the row (0.011), surfboard ($p < 0.001$) and air walker ($p = 0.027$) machines, with an effect size from low to moderate. In relation to the lumbar curvature and pelvic tilt, a significant decrease in lumbar lordosis and a decrease in pelvic anteversion were observed in the IP and FP in SBR and row; and in the bike ($p < 0.001$) machine, with an effect size from low to high. In the surfboard machine, a significant decrease in lumbar lordosis was found ($p = 0.002$), with a moderate effect size, with no changes in pelvic tilt.

ANCOVA analysis showed that sex was not an influential factor in the changes of sagittal spine disposition in the OFE ($F = 0.02$ – 2.672 ; $p = 0.123$ – 0.966), with the exception of pelvic tilt in the Bike ($F = 4.821$; $p = 0.034$). When the covariable height was analyzed, it was found that this covariate significantly influenced pelvic tilt in the OFE performed in sitting (SBR and Row in both IP and FP) ($F = 4.671$ – 5.391 ; $p = 0.025$ – 0.036), and thoracic curvature in the surfboard ($F = 5.866$; $p = 0.029$) (Table 2).

Table 3 shows bivariate correlations between spinal curvatures in the OFE and anthropometric variables. In almost cases anthropometric variables were correlated with the results obtained in the measurements of spinal curvatures. More specifically, body mass, BMI, waist-girth, hip girth, and biiliocrystal breadth were correlated with thoracic curvatures during the use of the OFE. Regarding lumbar curvatures, the anthropometric variables with significant correlations were height, hip girth, waist-hip ratio, and acromio-iliac index. However, pelvic tilt was the variables which showed a higher number of correlations with anthropometric variables. Correlations were found between pelvic tilt and height, waist-hip ratio, arm length, forearm length, upper limb length, biacromial breadth, and acromio-iliac index.

According to the multiple linear regression analysis (Table 4), the variables height and the cormic index explained most of the spinal changes during the use of the different OFE. More specifically, the subjects with a higher cormic index were more at risk of increasing their thoracic kyphosis in the SBR, row, bike, surfboard and air walker. In turn, those subjects with a higher cormic index showed a higher risk of decreasing lumbar lordosis towards kyphotic positions in the IP of the SBR, while those subjects with a higher height

Table 1 Characteristics of the participants.

Anthropometric variables	X ± SD	Spine variables	X ± SD
Body Mass (kg)	74.82 ± 13.69	Standing Thoracic curv. (°)	50.10 ± 10.67
Height (cm)	158.56 ± 9.64	Standing Lumbar curv. (°)	−31.85 ± 9.34
BMI	29.69 ± 4.27	Standing Pelvic tilt (°)	21.32 ± 7.31
Sitting height (cm)	82.68 ± 4.99	SBR IP Thoracic curv. (°)	46.92 ± 11.51
Cormic index	52.35 ± 1.44	SBR IP Lumbar curv. (°)	−2.64 ± 10.71
Waist girth (cm)	93.31 ± 11.40	SBR IP Pelvic tilt (°)	11.22 ± 8.50
Hip girth (cm)	104.60 ± 9.90	SBR FP Thoracic curv. (°)	52.24 ± 10.83
Waist-hip ratio	0.90 ± 0.09	SBR FP Lumbar curv. (°)	−14.59 ± 14.27
Arm length (cm)	31.48 ± 2.27	SBR FP Pelvic tilt (°)	9.73 ± 10.59
Forearm length (cm)	23.44 ± 1.95	Row IP Thoracic curv. (°)	47.63 ± 10.47
Upper limb length (cm)	54.95 ± 4.03	Row IP Lumbar curv. (°)	4.82 ± 9.47
Biacromial breadth (cm)	37.16 ± 1.94	Row IP Pelvic tilt (°)	2.49 ± 7.28
Biiliocrystal breadth (cm)	31.03 ± 2.20	Row FP Thoracic curv. (°)	53.71 ± 11.91
Acromio-iliac index	0.84 ± 0.06	Row FP Lumbar curv. (°)	−3.65 ± 14.74
		Row FP Pelvic tilt (°)	−4.25 ± 9.59
		Bike Thoracic curv. (°)	48.02 ± 11.68
		Bike Lumbar curv. (°)	−3.12 ± 11.75
		Bike Pelvic tilt (°)	14.80 ± 9.21
		Surfboard Thoracic curv. (°)	53.79 ± 10.59
		Surfboard Lumbar curv. (°)	−26.49 ± 12.75
		Surfboard Pelvic tilt (°)	22.42 ± 8.39
		Air walker Thoracic curv. (°)	52.33 ± 9.82
		Air walker Lumbar curv. (°)	−31.23 ± 10.20
		Air walker Pelvic tilt (°)	19.92 ± 8.17

Notes.

BMI, Body mass index; curv, curvature; FP, Final position; IP, Initial position; MIS, maximal isometric strength; SBR, Single bonny rider.

had a higher risk of decreasing lumbar lordosis towards kyphotic positions in the FP of the SBR and row, bike and surfboard machines. Likewise, taller subjects had a greater risk of decreasing pelvic anteversion towards pelvic retroversion positions in SBR, row and bike.

DISCUSSION

Most elderly people suffer from changes in the sagittal spine disposition in different positions, due to a loss of strength, muscle shortening, reduced mobility, and stiffness of passive structures such as ligaments and discs (Norasteh et al., 2019). Therefore, it is necessary to evaluate the spine disposition not only in standing, but also in different positions in daily life and sports practice in order to analyze the adaptations that occur during these activities (Abelleira-Lamela et al., 2020; López-Miñarro, García & Medina, 2009). However, most previous studies have only analyzed middle-aged and older adults in a standing position (Asai et al., 2017; Elsayed et al., 2018; Kasukawa et al., 2017; Keller et al., 2005; Ohyama et al., 2019). For this reason, in the present study, we analyzed the sagittal

Table 2 Analysis of the differences in the spine sagittal curvatures between the OFE and the standing position.

OFE-Position	Variable	Differences OFE-Standing			Model: Differences OFE-Standing x Sex			Model: Differences OFE-Standing x Height		
		X ± DS	p	df	Effect size (d)	F	p	η_p^2	F	p
SBR IP	Thoracic curv. (°)	-3.18 ± 9.00	.006	64	0.29	.011	.919	.001	.327	.576
	Lumbar curv. (°)	29.21 ± 12.27	<.001	64	2.91	.909	.352	.043	.066	.800
	Pelvic tilt (°)	-10.13 ± 9.39	<.001	64	1.27	.225	.638	.005	5.098	.029
SBR FP	Thoracic curv. (°)	2.14 ± 8.95	.053	64	0.20	.393	.540	.026	.202	.659
	Lumbar curv. (°)	17.25 ± 14.23	<.001	64	1.43	2.165	.157	.098	.008	.928
	Pelvic tilt (°)	-11.52 ± 9.50	<.001	64	1.27	.002	.966	.000	5.391	.025
Row IP	Thoracic curv. (°)	-1.96 ± 8.77	.046	64	0.23	.033	.859	.002	.044	.836
	Lumbar curv. (°)	36.67 ± 10.88	<.001	64	3.90	.968	.337	.046	.014	.908
	Pelvic tilt (°)	-18.12 ± 8.37	<.001	64	2.58	.036	.850	.001	5.179	.028
Row FP	Thoracic curv. (°)	2.76 ± 12.43	.011	64	0.32	.500	.490	.032	.493	.032
	Lumbar curv. (°)	28.19 ± 14.35	<.001	64	2.29	1.727	.204	.079	.522	.479
	Pelvic tilt (°)	-25.50 ± 10.11	<.001	64	3.00	.067	.796	.002	4.671	.036
Bike	Thoracic curv. (°)	-1.32 ± 11.13	.169	64	0.19	.203	.659	.013	.004	.952
	Lumbar curv. (°)	28.24 ± 13.19	<.001	64	2.71	2.544	.126	.113	.412	.528
	Pelvic tilt (°)	-6.13 ± 10.79	<.001	64	0.78	4.821	.034	.103	.511	.479
Surfboard	Thoracic curv. (°)	3.69 ± 7.39	<.001	64	0.35	2.672	.123	.151	5.866	.029
	Lumbar curv. (°)	4.62 ± 11.73	.002	64	0.48	.736	.401	.035	3.511	.076
	Pelvic tilt (°)	1.18 ± 6.05	.166	64	0.14	.937	.339	.022	.010	.920
Air walker	Thoracic curv. (°)	2.23 ± 7.62	.027	64	0.22	1.757	.205	.105	.790	.388
	Lumbar curv. (°)	0.62 ± 8.65	.558	64	0.06	.984	.333	.047	.001	.974
	Pelvic tilt (°)	-1.10 ± 6.06	.074	64	0.18	.827	.368	.019	.751	.391

Notes.

OFE, outdoor fitness equipment; IP, Initial position; FP, Final position; curv, curvature; SBR, Single bony rider.

Table 3 Bivariate correlations between spinal curvatures in the outdoor fitness machines and anthropometric variables.

	Body mass	Height	BMI	Sitting height	Comm. index	Waist girth	Hip girth	Waist ratio	Arm length	Forearm length	Upper limb length	Biacromial breadth	Biiliacral breadth	Acromio-iliac index
Standing Thoracic curv.	$r = -0.307$ $p = 0.013$	$r = 0.111$ $p = 0.377$	$r = 0.216$ $p = 0.019$	$r = -0.081$ $p = 0.628$	$r = -0.367$ $p = 0.003$	$r = 0.421$ $p = 0.000$	$r = 0.254$ $p = 0.041$	$r = -0.277$ $p = 0.040$	$r = 0.288$ $p = 0.031$	$r = 0.207$ $p = 0.098$	$r = 0.249$ $p = 0.046$	$r = 0.145$ $p = 0.218$	$r = 0.246$ $p = 0.086$	$r = 0.327$ $p = 0.027$
Standing Lumbar curv.	$r = -0.231$ $p = 0.064$	$r = -0.172$ $p = 0.088$	$r = -0.139$ $p = 0.219$	$r = -0.172$ $p = 0.171$	$r = -0.097$ $p = 0.442$	$r = -0.079$ $p = 0.501$	$r = -0.231$ $p = 0.044$	$r = -0.221$ $p = 0.055$	$r = -0.239$ $p = 0.031$	$r = -0.172$ $p = 0.170$	$r = -0.215$ $p = 0.085$	$r = -0.011$ $p = 0.931$	$r = -0.178$ $p = 0.172$	$r = -0.157$ $p = 0.157$
Standing Pelvic tilt	$r = 0.110$ $p = 0.381$	$r = 0.008$ $p = 0.762$	$r = 0.130$ $p = 0.301$	$r = 0.073$ $p = 0.562$	$r = 0.001$ $p = 0.990$	$r = -0.097$ $p = 0.603$	$r = 0.257$ $p = 0.039$	$r = -0.299$ $p = 0.013$	$r = 0.001$ $p = 0.999$	$r = -0.035$ $p = 0.783$	$r = -0.008$ $p = 0.958$	$r = -0.128$ $p = 0.061$	$r = 0.138$ $p = 0.269$	$r = 0.239$ $p = 0.029$
SRR IP Thoracic curv.	$r = 0.298$ $p = 0.016$	$r = 0.109$ $p = 0.388$	$r = 0.302$ $p = 0.015$	$r = 0.043$ $p = 0.615$	$r = -0.119$ $p = 0.236$	$r = 0.425$ $p = 0.000$	$r = 0.247$ $p = 0.047$	$r = -0.266$ $p = 0.039$	$r = 0.256$ $p = 0.039$	$r = 0.168$ $p = 0.160$	$r = 0.223$ $p = 0.075$	$r = 0.104$ $p = 0.411$	$r = 0.206$ $p = 0.050$	$r = 0.110$ $p = 0.322$
SRR IP Lumbar curv.	$r = -0.057$ $p = 0.652$	$r = 0.024$ $p = 0.849$	$r = -0.094$ $p = 0.156$	$r = -0.088$ $p = 0.483$	$r = -0.238$ $p = 0.005$	$r = 0.238$ $p = 0.005$	$r = -0.329$ $p = 0.009$	$r = -0.327$ $p = 0.008$	$r = 0.014$ $p = 0.915$	$r = -0.012$ $p = 0.927$	$r = 0.002$ $p = 0.990$	$r = 0.188$ $p = 0.135$	$r = -0.222$ $p = 0.009$	$r = -0.322$ $p = 0.009$
SRR IP Pelvic tilt	$r = -0.199$ $p = 0.113$	$r = -0.402$ $p = 0.001$	$r = 0.086$ $p = 0.480$	$r = -0.236$ $p = 0.065$	$r = -0.364$ $p = 0.003$	$r = -0.194$ $p = 0.022$	$r = 0.232$ $p = 0.003$	$r = -0.432$ $p = 0.000$	$r = -0.412$ $p = 0.001$	$r = -0.354$ $p = 0.004$	$r = -0.399$ $p = 0.001$	$r = -0.477$ $p = 0.000$	$r = -0.003$ $p = 0.978$	$r = 0.352$ $p = 0.004$
SRR FP Thoracic curv.	$r = 0.179$ $p = 0.175$	$r = -0.110$ $p = 0.382$	$r = 0.328$ $p = 0.008$	$r = -0.147$ $p = 0.244$	$r = -0.087$ $p = 0.490$	$r = 0.401$ $p = 0.001$	$r = 0.239$ $p = 0.037$	$r = -0.218$ $p = 0.081$	$r = 0.082$ $p = 0.518$	$r = 0.007$ $p = 0.956$	$r = 0.048$ $p = 0.706$	$r = -0.057$ $p = 0.649$	$r = 0.134$ $p = 0.288$	$r = 0.186$ $p = 0.132$
SRR FP Lumbar curv.	$r = 0.024$ $p = 0.851$	$r = 0.274$ $p = 0.027$	$r = -0.226$ $p = 0.078$	$r = -0.181$ $p = 0.150$	$r = -0.194$ $p = 0.121$	$r = -0.007$ $p = 0.955$	$r = -0.368$ $p = 0.003$	$r = 0.331$ $p = 0.007$	$r = 0.226$ $p = 0.070$	$r = 0.247$ $p = 0.048$	$r = 0.245$ $p = 0.049$	$r = 0.311$ $p = 0.012$	$r = -0.305$ $p = 0.013$	$r = -0.305$ $p = 0.013$
SRR FP Pelvic tilt	$r = -0.122$ $p = 0.335$	$r = -0.328$ $p = 0.008$	$r = 0.135$ $p = 0.282$	$r = -0.242$ $p = 0.052$	$r = 0.178$ $p = 0.156$	$r = -0.090$ $p = 0.674$	$r = 0.236$ $p = 0.058$	$r = -0.316$ $p = 0.011$	$r = -0.328$ $p = 0.007$	$r = -0.297$ $p = 0.016$	$r = -0.326$ $p = 0.008$	$r = -0.338$ $p = 0.003$	$r = 0.017$ $p = 0.892$	$r = 0.286$ $p = 0.020$
Row IP Thoracic curv.	$r = 0.209$ $p = 0.095$	$r = 0.055$ $p = 0.664$	$r = 0.234$ $p = 0.081$	$r = 0.039$ $p = 0.756$	$r = -0.086$ $p = 0.478$	$r = 0.262$ $p = 0.025$	$r = 0.192$ $p = 0.124$	$r = 0.116$ $p = 0.358$	$r = 0.112$ $p = 0.373$	$r = 0.145$ $p = 0.249$	$r = 0.133$ $p = 0.402$	$r = 0.178$ $p = 0.089$	$r = 0.169$ $p = 0.155$	$r = 0.179$ $p = 0.179$
Row IP Lumbar curv.	$r = -0.179$ $p = 0.153$	$r = 0.132$ $p = 0.296$	$r = 0.303$ $p = 0.003$	$r = 0.078$ $p = 0.538$	$r = -0.104$ $p = 0.410$	$r = -0.157$ $p = 0.213$	$r = -0.478$ $p = 0.000$	$r = 0.242$ $p = 0.053$	$r = 0.065$ $p = 0.668$	$r = 0.013$ $p = 0.919$	$r = 0.042$ $p = 0.742$	$r = 0.113$ $p = 0.370$	$r = -0.282$ $p = 0.155$	$r = -0.282$ $p = 0.155$
Row IP Pelvic tilt	$r = -0.010$ $p = 0.937$	$r = -0.421$ $p = 0.000$	$r = 0.384$ $p = 0.003$	$r = -0.336$ $p = 0.007$	$r = 0.182$ $p = 0.148$	$r = 0.039$ $p = 0.811$	$r = 0.455$ $p = 0.000$	$r = -0.367$ $p = 0.003$	$r = -0.401$ $p = 0.001$	$r = -0.357$ $p = 0.003$	$r = -0.395$ $p = 0.001$	$r = -0.379$ $p = 0.002$	$r = 0.366$ $p = 0.003$	$r = 0.366$ $p = 0.003$
Row FP Thoracic curv.	$r = 0.371$ $p = 0.002$	$r = -0.005$ $p = 0.969$	$r = 0.492$ $p = 0.000$	$r = -0.492$ $p = 0.000$	$r = -0.072$ $p = 0.569$	$r = 0.478$ $p = 0.000$	$r = 0.485$ $p = 0.000$	$r = 0.104$ $p = 0.408$	$r = 0.062$ $p = 0.622$	$r = 0.081$ $p = 0.519$	$r = 0.074$ $p = 0.557$	$r = 0.094$ $p = 0.504$	$r = 0.353$ $p = 0.003$	$r = 0.359$ $p = 0.003$
Row FP Lumbar curv.	$r = -0.177$ $p = 0.139$	$r = 0.215$ $p = 0.049$	$r = -0.451$ $p = 0.000$	$r = 0.178$ $p = 0.137$	$r = -0.134$ $p = 0.286$	$r = -0.136$ $p = 0.280$	$r = -0.614$ $p = 0.000$	$r = 0.398$ $p = 0.001$	$r = 0.256$ $p = 0.039$	$r = 0.137$ $p = 0.276$	$r = 0.207$ $p = 0.098$	$r = 0.212$ $p = 0.089$	$r = -0.461$ $p = 0.000$	$r = -0.461$ $p = 0.000$
Row FP Pelvic tilt	$r = -0.012$ $p = 0.922$	$r = -0.320$ $p = 0.009$	$r = 0.262$ $p = 0.035$	$r = -0.245$ $p = 0.049$	$r = 0.156$ $p = 0.216$	$r = -0.018$ $p = 0.884$	$r = 0.323$ $p = 0.009$	$r = -0.306$ $p = 0.012$	$r = -0.296$ $p = 0.030$	$r = -0.209$ $p = 0.094$	$r = -0.250$ $p = 0.045$	$r = -0.337$ $p = 0.006$	$r = 0.293$ $p = 0.018$	$r = 0.293$ $p = 0.018$
Bike Thoracic curv.	$r = 0.308$ $p = 0.002$	$r = 0.091$ $p = 0.466$	$r = 0.394$ $p = 0.001$	$r = 0.089$ $p = 0.477$	$r = -0.012$ $p = 0.926$	$r = 0.431$ $p = 0.000$	$r = 0.326$ $p = 0.008$	$r = 0.195$ $p = 0.116$	$r = 0.206$ $p = 0.098$	$r = 0.146$ $p = 0.241$	$r = 0.186$ $p = 0.134$	$r = 0.143$ $p = 0.252$	$r = 0.223$ $p = 0.072$	$r = 0.106$ $p = 0.397$
Bike Lumbar curv.	$r = -0.011$ $p = 0.929$	$r = 0.115$ $p = 0.359$	$r = -0.123$ $p = 0.325$	$r = 0.046$ $p = 0.716$	$r = -0.150$ $p = 0.230$	$r = -0.045$ $p = 0.722$	$r = -0.284$ $p = 0.021$	$r = 0.209$ $p = 0.092$	$r = 0.057$ $p = 0.648$	$r = 0.074$ $p = 0.553$	$r = 0.098$ $p = 0.586$	$r = 0.165$ $p = 0.187$	$r = -0.198$ $p = 0.112$	$r = -0.323$ $p = 0.008$
Bike Pelvic tilt	$r = 0.391$ $p = 0.001$	$r = -0.333$ $p = 0.006$	$r = 0.496$ $p = 0.000$	$r = -0.251$ $p = 0.042$	$r = 0.178$ $p = 0.153$	$r = 0.124$ $p = 0.319$	$r = 0.304$ $p = 0.001$	$r = -0.328$ $p = 0.007$	$r = -0.325$ $p = 0.008$	$r = -0.307$ $p = 0.004$	$r = -0.351$ $p = 0.001$	$r = -0.306$ $p = 0.002$	$r = 0.385$ $p = 0.001$	$r = 0.385$ $p = 0.001$
Surfboard Thoracic curv.	$r = 0.291$ $p = 0.019$	$r = 0.107$ $p = 0.396$	$r = 0.398$ $p = 0.016$	$r = 0.056$ $p = 0.667$	$r = -0.121$ $p = 0.337$	$r = 0.406$ $p = 0.001$	$r = 0.311$ $p = 0.012$	$r = 0.135$ $p = 0.199$	$r = 0.206$ $p = 0.100$	$r = 0.175$ $p = 0.352$	$r = 0.170$ $p = 0.376$	$r = 0.084$ $p = 0.762$	$r = 0.289$ $p = 0.030$	$r = 0.289$ $p = 0.030$
Surfboard Lumbar curv.	$r = 0.167$ $p = 0.184$	$r = 0.211$ $p = 0.000$	$r = -0.228$ $p = 0.068$	$r = 0.109$ $p = 0.001$	$r = -0.224$ $p = 0.073$	$r = 0.079$ $p = 0.532$	$r = -0.276$ $p = 0.026$	$r = -0.351$ $p = 0.004$	$r = 0.441$ $p = 0.000$	$r = 0.443$ $p = 0.000$	$r = 0.452$ $p = 0.000$	$r = 0.356$ $p = 0.004$	$r = -0.326$ $p = 0.001$	$r = -0.326$ $p = 0.001$
Surfboard Pelvic tilt	$r = 0.176$ $p = 0.16$	$r = 0.012$ $p = 0.927$	$r = 0.328$ $p = 0.007$	$r = 0.028$ $p = 0.823$	$r = 0.037$ $p = 0.767$	$r = 0.027$ $p = 0.829$	$r = 0.311$ $p = 0.001$	$r = -0.353$ $p = 0.002$	$r = -0.325$ $p = 0.005$	$r = -0.305$ $p = 0.007$	$r = -0.301$ $p = 0.001$	$r = -0.041$ $p = 0.725$	$r = 0.197$ $p = 0.117$	$r = 0.197$ $p = 0.117$
Air walker Thoracic curv.	$r = 0.11$ $p = 0.012$	$r = 0.106$ $p = 0.126$	$r = 0.356$ $p = 0.008$	$r = 0.025$ $p = 0.896$	$r = -0.169$ $p = 0.179$	$r = 0.403$ $p = 0.001$	$r = 0.324$ $p = 0.009$	$r = -0.170$ $p = 0.176$	$r = 0.177$ $p = 0.157$	$r = 0.131$ $p = 0.13$	$r = 0.161$ $p = 0.101$	$r = 0.169$ $p = 0.056$	$r = 0.278$ $p = 0.023$	$r = 0.278$ $p = 0.023$
Air walker Lumbar curv.	$r = -0.115$ $p = 0.077$	$r = -0.005$ $p = 0.952$	$r = -0.109$ $p = 0.367$	$r = -0.082$ $p = 0.538$	$r = -0.065$ $p = 0.605$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$	$r = -0.205$ $p = 0.031$
Air walker Pelvic tilt	$r = 0.244$ $p = 0.003$	$r = 0.045$ $p = 0.712$	$r = 0.139$ $p = 0.309$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$	$r = -0.031$ $p = 0.803$

Notes:
SRR, Single bonny rider; curv, curvature; FP, Final Position; IP, Initial Position.

Table 4 Stepwise multiple linear regression analysis of the relationship of differentiation of spinal curvatures in the outdoor fitness machines with anthropometric variables.

	Difference OFE-standing	R ²	p Value	Included independent variables	Standardized Coefficient (β)
SBR	IP Thoracic curv. (°)	.060	.049	Cormic index	0.245
	IP Lumbar curv. (°)	.080	.023	Cormic index	0.283
	IP Pelvic tilt (°)	.160	.001	Height	−0.400
	FP Thoracic curv. (°)	.111	.007	Cormic index	0.332
	FP Lumbar curv. (°)	.172	.001	Height	0.415
	FP Pelvic tilt (°)	.163	.001	Height	−3.486
Row	IP Thoracic curv. (°)	.175	.001	Cormic index	0.419
	IP Lumbar curv. (°)	.089	.016	Height	0.298
	IP Pelvic tilt (°)	.197	.000	Height	−0.444
	FP Lumbar curv. (°)	.152	.001	Height	0.390
Bike	FP Pelvic tilt (°)	.114	.006	Height	−0.338
	Thoracic curv. (°)	.158	.001	Cormic index	0.398
	Lumbar curv. (°)	.100	.010	Height	0.316
Surfboard	Pelvic tilt (°)	.137	.002	Height	−0.370
	Thoracic curv. (°)	.127	.004	Cormic index	0.357
Air walker	Lumbar curv. (°)	.368	.000	Height	0.606
	Thoracic curv. (°)	.088	.016	Cormic index	0.297

Notes.

OFE, outdoor fitness equipment; SBR, Single bonny rider; curv, curvature; FP, Final Position; IP, Initial Position.

disposition of the spine of middle-aged and older adults in standing position, but also in the different OFE that are most frequently installed in the bio-healthy parks.

The main finding of the present investigation was that in general, there were significant differences in the sagittal spine disposition and pelvic tilt during the execution of the exercises with the machines, as compared to the relaxed standing position in middle-age and older adults.

In the OFE that were performed in the two-legged position, as was the case with the surfboard and air walker, an increase in thoracic kyphosis was found when using these OFE, without changes in lumbar curvature or pelvic tilt in general. Coinciding with these results, previous studies have shown that when a frontal grip has to be performed, with internal rotation and/or shoulder adduction, it is common to find greater thoracic kyphosis than in a relaxed standing position (Abelleira-Lamela et al., 2020; López-Miñarro, Rodríguez-García & Santonja Medina, 2010; Muyor, 2015), especially in the event that this provision is accompanied by a maintained grip (Imagama et al., 2014; Kordi-Yoosefinejad et al., 2019). This is especially relevant considering that the presence of hyperkyphotic thoracic curvatures during the execution of fitness exercises could lead to a lower involvement of the musculature that is mainly involved in the exercise. This could result in a greater shortening of the flexor and internal rotator muscles in the shoulder, a decrease in joint mobility, and changes in biomechanics and in the position of the center of gravity, among other factors

(*Imagama et al., 2014; Kordi-Yoosefinejad et al., 2019*), which could increase the risk of falls, back pain and loss of function (*Norasteh et al., 2019*).

In the sedentary machines, the grip was in a more neutral position and with less activation of the upper limb musculature, which could influence the degree of tension of the stabilizing musculature in the scapulo-humeral joint and the thoracic area to adopt more neutral positions (*Imagama et al., 2014; Kordi-Yoosefinejad et al., 2019*). However, in sedentary exercises performed in OFE, there was a decrease in lumbar lordosis and pelvic anteversion. Previous studies found the same tendency toward decreased lumbar lordosis and pelvic anteversion when analyzing the disposition of the spine and pelvic tilt during sedentary exercise positions in older individuals (*Norasteh et al., 2019*). This disposition was also found during other sports actions that required executing force from a sitting position (*Abelleira-Lamela et al., 2020; López-Miñarro, Rodríguez-García & Santonja Medina, 2010; Muyor, 2015*). More specifically, previous studies found that in the case of starting from a sedentary, sitting position, the technical gesture requires performing a pulling movement with the upper limbs fully extended, the trunk inclined and the knees semi-extended, as is the case of row and SBR, there was an adaptation in the pelvic tilt and lumbar disposition (*Abelleira-Lamela et al., 2020; López-Miñarro, Muyor & Alacid, 2012*). This is especially relevant if we take into account that people who adopt a kyphotic position in the lumbar area in situations of load mobilization have a higher probability of suffering pathologies such as herniated and protruded discs, low back pain, spondylolysis and spondylolisthesis, among others (*McGill, Cannon & Andersen, 2014*). Therefore, it would be advisable to modify the design of this type of machines to allow for a normal disposition of the lumbar spine during the execution of guided exercises (*McGill, Cannon & Andersen, 2014*). Despite these promising results, questions still remain.

Another of the objectives of the present investigation was to analyze whether anthropometric variables could condition the sagittal disposition of the spine and pelvic tilt during the use of the OFE, finding that anthropometric variables significantly influenced the adaptations in the sagittal spine disposition and pelvic tilt. Previous studies have already pointed out that anthropometric variables could condition the sagittal spine disposition when performing actions involving the application of force (*Abelleira-Lamela et al., 2020; Elsayed et al., 2018*). However, until now, no studies had been conducted which analyzed this issue in OFE.

More specifically, it was found that in general, the users with a greater height and/or with a higher cormic index, whose sitting height was proportionally larger than the sitting height, were more likely to be taller (*Esparza-Ros, Vaquero-Cristóbal & Marfell-Jones, 2019*), have a greater probability of presenting kyphotic thoracic curves, as well as kyphotic positions of the lumbar area, together with a greater probability of showing pelvic retroversion in the machines that were executed in a sedentary position. In addition, in the ANCOVA analysis, height was found to be a covariate that significantly influenced pelvic tilt in the OFE performed in sitting in the IP and FP, as well as thoracic curvature in the surfboard. The differences in pelvic tilt may have been due to the participants were sitting on the OFE and the taller subject will be able to perform the grips in a more upright position, thus requiring less pelvic tilt in terms of grip as it has been found using other kinds of sport

equipment (Abelleira-Lamela et al., 2020; López-Miñarro, Muyor & Alacid, 2012; Muyor, 2015). Regarding thoracic curvature, it was found that height influenced the surfboard, but not the air walker, even though both were in standing position. This could be due to the grip, since the air walker has a higher frontal grip, while the surfboard has a lateral grip at hip height, so that a greater trunk flexion is required to maintain the grip. Previous studies have already found that the number of subjects with thoracic hyperkyphosis is higher in this type of position when there is no proper postural hygiene (Farrag et al., 2015; Mawston, McNair & Boocock, 2007).

In contrast, the anthropometric parameters related to the transverse dimension had no influence on the sagittal disposition of the spine in middle-aged or older adults. This could be a consequence of the fact that one of the problems presented by the OFE in relation to ergonomics is that it cannot be adjusted according to the anthropometric characteristics of the users (Chow & Wu, 2019), in contrast to what happens in the classic fitness room equipment (Chow & Wu, 2019). Thus, it is likely that in those subjects who are taller or whose trunk is longer, the grip remains low, having to perform a thoracic hyperkyphosis in order to hold themselves. The disposition of the thoracic spine could in turn condition the disposition of the lumbar curvature and pelvic tilt (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015), which would explain the presence of inversions in the lumbar area and pelvic retroversion positions accompanying thoracic hyperkyphosis dispositions, especially when the execution has to be carried out from a sedentary position (López-Miñarro et al., 2017; Vaquero-Cristóbal et al., 2015). This tendency towards flattening of the lumbar curvature and pelvic tilt observed in the sagittal spine disposition during the use of OFE would be contrary to the ideal position. In this regard, the curved disposition of the spine in the sagittal plane is essential, as the strength of an element is equal to the number of curvatures squared plus one (Kapandji, 1981), the almost aligned disposition of the lumbar spine and the pelvic tilt would detract from the strength of the spine. In addition, the spine is more resistant to axial compression and more stable with the presence of these curves than without them (Panjabi et al., 1985), allowing for an efficient absorption of the loads applied to the spine (Adams & Dolan, 1996; Kapandji, 1981) and increasing the efficiency of the paravertebral musculature (Dickson, 2004). Therefore, the misalignments of the thoracic and lumbar curvatures, together with the external load caused by the performance of the exercises, could increase intervertebral stress and spinal loads (Keller et al., 2005). For all these reasons, it would be necessary to redesign the OFE, evolving towards models that would allow adjusting the distances between footrests, seats and grips according to the size and seated size of middle-aged and older adults.

Another of the objectives of the present investigation was to analyze whether the sex covariate influenced the changes that occurred in the sagittal spine disposition on the OFE. A much debated question is whether sex influence sagittal spine disposition. Specifically, some papers have found that women show a greater probability of presenting lumbar hyperlordosis than men in adulthood (Bailey et al., 2016), while others have showed similarity in the sagittal spine disposition between men and women (Endo et al., 2012; Janssen et al., 2009; Yeh et al., 2018). In the present investigation it was found that sex did not influence the sagittal spine disposition and pelvic tilt adopted in the OFE. This could

be due to the fact that other factors are affecting the adaptations that occur in the sagittal arrangement of the spine when using this type of fitness equipment.

As a strength of the research, this is the first study that analyzes the disposition of the spine in the OFE, and the sample investigated was large. Regarding the limitations of the present study, although the sample of the present study was large as compared to other, similar studies, the sample of men was somewhat reduced, perhaps because men do not find these types of machines useful and, therefore, this is another reason to investigate the safety and effectiveness of the OFE. In addition, since we only had one model of each machine and not different prototypes of each one, we could not analyze the influence of changes in the disposition of the machines on the sagittal spine disposition. Thus, this could be a future line of research with which to analyze whether the modification of the OFE allows for a safer and healthier sagittal spine disposition and pelvic tilt of its users. On the other hand, it will be possible to contrast the results of the present investigation in professional equipment that does allow an adaptation of the equipment according to the anthropometric characteristics of the user, such as fitness equipment as well as looking for new ways of using the machines to make them as versatile as possible. Another limitation of the present investigation was that the evolution of low back pain or other spinal pathologies during the use of OFE was not analyzed. This should be addressed in future research.

CONCLUSIONS

Middle-aged and older adults show spinal misalignments when using the OFE with respect to the standing position, showing a significant decrease in the thoracic kyphosis in the IP of SBR and ROW, and a significant increase in the surfboard and air walker, and in the FP of Row; a significant decrease in the lumbar lordosis in all OFE with the exception of the air walker; and a significant decrease in the pelvic anteversion in all the OFE in sitting (SBR, Bike and Row). Height and the cormic index conditioned these adaptations, showing that middle-aged and older-adults with higher height and cormic index had a higher probability of showing increased thoracic kyphosis, lumbar kyphosis, and pelvic retroversion. This are the reason for the recommendation of the manufacturing of safer outdoor fitness equipment that allows users to adjust them to their anthropometric needs.

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The authors declare there are no competing interests.

Author Contributions

- Tomás Abelleira-Lamela performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Raquel Vaquero-Cristóbal and Noelia González-Gálvez conceived and designed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Francisco Esparza-Ros conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Alejandro Espeso-García performed the experiments, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Pablo Jorge Marcos-Pardo conceived and designed the experiments, performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

Human Ethics

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The Catholic University of Murcia granted Ethical approval to carry out the study (Ethical Application Ref: CE111908)

Data Availability

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OPEN Improving spinal alignment through innovative resistance training with outdoor fitness equipment in middle-aged and older adults: a randomized controlled trial

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The main objective of this study was to analyze the effect of a resistance training program using outdoor fitness equipment (OFE) on sagittal spine disposition and pelvic tilt in middle-aged and older adults. One hundred and twenty-eight middle-aged and older adults were randomly assigned to the training (TG) or control group (CG). The TG trained for 8 weeks, with 2 weekly sessions of one hour of resistance circuit training with OFE. Before and after the intervention, the sagittal spine disposition and pelvic tilt in the relaxed standing and sitting positions were analyzed. The results showed that the TG obtained a significant reduction ($p < 0.001$) in all the curvatures of the sagittal spine disposition and pelvic tilt in the standing position after the intervention, in contrast to the CG, which only showed a significant reduction in pelvic tilt ($p = 0.005$). Regarding the sitting position, only the TG presented a significant decrease in lumbar lordosis ($p < 0.001$). In conclusion, resistance training with OFE may be useful in improving sagittal spine disposition in middle-aged and older adults. Given the availability of free OFE in parks, the present research provides elders with an accessible and effective training program to curb the effects of ageing on the sagittal spine disposition.

Keywords Aging, Ergonomic, Guided exercise equipment, Hyperkyphosis, Outdoor gym, Posture

Current scientific evidence describes an increase in thoracic curvature while standing as a person ages^{1–3}, without a clear trend for lumbar curvature in the standing position in this population. While some studies find that it often flattens during this stage, other studies show that it increases^{4–6}. Not surprisingly, previous studies have found that 20–40% of older adults have thoracic hyperkyphosis in the standing position^{7–9}, with the incidence of older adults showing hyperlordosis in the standing position also being high⁹.

This increase has been linked to a poorer health status, characterized by respiratory problems, greater loss of physical function, lack of mobility, risk of falling, back pain in general, and low back pain in particular, and even mortality^{1,10–15}. In addition, pathologies such as spondylolysis, spondylolisthesis or degenerative changes in the intervertebral discs have also been linked to spine misalignments^{16,17}.

One of the factors that could be associated with the increase in sagittal curvatures of the spine beyond the normal range with age is the loss of physical conditioning¹. A relationship has also been found between changes occurring in the sagittal spine disposition and loss of strength^{12,18–21}. Specifically, it has been found that a deficit

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in the strength of the extensor muscles of the trunk is related to an increase in thoracic hyperkyphosis and hyperlordosis or rectification of the lumbar area, as well as an alteration of the lumbo-pelvic dynamics^{1,13,19,20}. In addition, strength deficits in the trunk muscles, with the subsequent changes in the sagittal spine disposition, increase the risk of suffering from some pathologies such as herniated discs¹⁷.

As a result of the aforementioned factors, various studies have suggested the implementation of comprehensive exercise training programs, with a specific emphasis on resistance training to enhance sagittal spinal disposition^{22–24}. Thus, most of these studies have implemented multicomponent programs, usually including stretching or postural hygiene exercises together with resistance work as well^{14,25}. Therefore, the effect of exclusive resistance training on the sagittal spine disposition is lightly studied but promising^{14,26–28}. In addition, very few of these studies have focused on the adult/older population^{26–29}. Likewise, reviews on the effect of strength training on spinal disposition have shown that a full body circuit based on different types of overload training, such as using gym equipment, dumbbells, or weighted backpacks, can improve thoracic alignment in elders as long as sufficient overload and training volume is achieved³⁰. This could be due to the fact that in most of these interventions, the trunk musculature is not worked on exclusively, but most of the exercises focus on the upper and lower limb musculature, with the trunk musculature being involved as a synergist, so that the generation of sufficient overload seems to be a limiting factor in the effects of these interventions on the sagittal spine disposition³⁰. However, these interventions have been focused on different methodologies used for strength training, such as gym equipment, self-loading exercises, dumbbells, weighted backpacks or elastic bands, with very different results reported between them, which could be due to the differences in the training programs proposed, the training volume, the overloading of the different training systems used, or the characteristics of the population included³⁰.

In this line, despite the many investigations carried out with different types of equipment, including traditional machines^{31,38}, it should be noted that none of these previous studies have used outdoor fitness equipment (OFE) for resistance training. In general, OFE machines are specially designed for adults and older adults, with a friendly design and a simple operation^{32,33}. Many public entities worldwide have used them with the aim of achieving a healthy aging of the population by making access to OFE simple and free of charge^{34,35}. The location of these machines in public spaces and their free-of-charge use, provide greater availability and accessibility as compared to traditional machines. In addition, although they are more oriented towards the elderly population, they are commonly used by people of all age groups³³, so that a larger population group in multiple countries³⁴ could benefit from their use over traditional gym machines. In fact, this type of installation has been booming in recent years.

OFE is a very interesting option for guided resistance training with exercise equipment. Theoretically, training with OFE should influence the sagittal spine disposition by strengthening the adjoining and stabilizing trunk and back musculature such as abdominal obliques, rectus abdominis, multifidus, transverse abdominal, quadratus lumborum, erector spinae or dorsal, among others^{36–38}. These muscles act as synergists when pulling or pushing with the upper limb, or movements involving hip flexions or extensions, movements for which many OFE are designed³⁹. In fact, previous studies have shown that training on OFE-like machines such as guided gym machines can improve sagittal spine posture as a result of the activation generated by these machines in synergist muscles that act as stabilizing musculature of the trunk and back^{25,30,40–42}. However, although OFE machines are training devices with certain similarities to traditional gym machines, unlike traditional gym machines in the OFE the user's own weight is used as the load by means of a system of levers^{37,43}. Previous studies have shown that their use can improve body composition and functionality, and increase strength in arms and legs³⁹. Furthermore, OFEs have been designed without regard to safety or ergonomic principles³⁵. This therefore raises the question of whether the OFE machines can achieve long-term beneficial effects on the sagittal disposition of the spine despite their design, or provide sufficient stimulus, as has been found with other strength training systems⁴⁷. It is therefore essential to know the effects of training with this type of equipment on the sagittal spine disposition.

Therefore, the aim of the present study was to analyze the effect of a resistance training program using OFE on the sagittal spine disposition and pelvic tilt of middle-aged and older adults. The hypothesis of the present study is that resistance training with OFE will improve the sagittal spine disposition and pelvic tilt of middle-aged and older adults.

Materials and methods

Study design

The present study is an 8-week randomized controlled trial. The trial design was registered with ClinicalTrials.gov (identifier: NCT04958499) and followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines and the Template for Intervention Description and Replication (TIDieR) checklist. The research was conducted in accordance with the Declaration of Helsinki. Approval was obtained from the Ethics Committee of the Universidad Católica San Antonio de Murcia (Ethical Application Ref: CE111908) before the start of the project. All participants were informed of the study evidence as well as any potential risks and possible adverse effects, and voluntarily signed an informed consent form prior to the measurements and intervention, and also provided their consent to have their photographs taken for subsequent publications.

Participants

The minimum sample size necessary for the study's development was calculated using Rstudio 3.15.0 software (Rstudio Inc., USA), and followed the methodology employed in previous studies⁴⁴, which also provided the standard deviation (SD) from prior studies that measured thoracic kyphosis in standing position for a sample of older adults (SD = 8.5°)²⁶. This standard deviation was chosen after selecting a study that showed a sample similar to the present one. In addition, to be conservative, a standard deviation that was slightly higher than the

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norm was used to ensure the sample and power size. With an estimated error (d) of 2.12, a confidence interval of 95%, a significance power of 95% ($1-\beta=0.95$), and a significance level of 0.05, the required sample size was determined to be 62 volunteers. To be cautious and to avoid a high sample loss after the end of the intervention, a dropout rate of 20% was assumed, based on previous studies^{26,45} that had similar characteristics to the present one. Thus, a minimum of 74 participants per group was required.

The participants were recruited on a voluntary basis through informative conferences and advertising in different senior centers in the Region of Murcia (Spain). The inclusion criteria were: a) being over 50 years of age; and b) not performing resistance training or physical exercise regularly. The exclusion criteria were: a) suffering from any spinal disorder or injury that prevented the performance of the measurements and/or training; b) having undergone surgery that prevents/poses a risk towards performing any of the tests and/or training; c) presenting any neurological, cardiovascular, musculoskeletal or metabolic alterations at the time of the measurement/training; d) missing the post-test evaluations; and e) starting to perform physical exercise systematically during the time of the study. The final sample consisted of 128 middle-aged and older adults, 46 men (mean age: 60.50 ± 5.96 years) and 82 women (mean age: 58.04 ± 7.62). They were randomized into the training group (TG) (n=64; 24 males and 40 females; mean age: 60.02 ± 7.25 years) and control group (CG) (n=64; 22 males and 42 females; mean age: 57.83 ± 6.92 years). The CONSORT flow diagram is shown in Fig. 1.

Randomization and blinding

After the recruitment and selection of the sample, the participants were assigned to the different groups. The group assignment was blinded and was carried out using a computer-generated random number table by a researcher in the presence of other researchers unrelated to the present investigation. Two groups were established according to the thoracic curve, as in previous research⁴⁶, and then a random sequence was generated to create the groups by stratified randomization. The researchers who performed the spinal measurements were not present at the training sessions. The two researchers involved in data collection were also cross-blinded in the measurements, where one carried out the measurement using the device, while the other was only responsible for verifying the correct recording of the data. During randomization, an attempt was made to keep married couples in the same group, as well as social groups, to increase adherence, following the methodology from previous studies⁴⁷.

Measurements

The measurements were performed in a sports science laboratory at a standardized temperature of 24 °C between 10:00 and 14:00 h. The participants were requested to not stretch or warm up prior to the tests. During the measurements, the participants remained barefoot on an insulating mat.

First, the basic variables of body mass and height were measured according to the protocol from the International Society for the Advancement of Anthropometry (ISAK)⁴⁸. All the measurements were performed by an ISAK Level 1 accredited anthropometrist. A Tanita BC-545N scale (Tanita, Arlington Heights, Illinois, USA) was used to measure body mass. A HR001 portable stadiometer (Tanita, Arlington Heights, Illinois, USA) was used to measure height.

Subsequently, the sagittal spine disposition and pelvic tilt were measured using the Spinal Mouse® system (Idiag, Fehraltorf, Switzerland). This device allows the angular measurement of the different spinal curvatures in a non-invasive way by means of a wireless device connected to a computer. This tool has shown high intra- and inter observer validity and reliability, with the following correlation coefficients, respectively (0.61–0.96; 0.70–0.93)⁴⁹. An assessment of the sagittal spine disposition and pelvic tilt in relaxed standing and sitting positions was performed, following the protocol from previous studies^{50,51}. In the standing position, the volunteers stood with their shoulders relaxed, looking forward, with their arms along their trunk, and their feet hip-width apart. For the sitting position, the volunteers were placed in a relaxed sitting position on a box, without thoracic or lumbar support, with their hands resting on their thighs, and with their knees bent at 90°. A positive value implied a pelvic kyphosis/anteversion, while a negative value implied a pelvic lordosis/retroversion. All the assessments were performed by the same measurer, who had previous experience in performing similar interventions.

Intervention

The intervention program was carried out in an OFE circuit, consisting of eight OFE machines (Bonny rider, Air Walker, Surfboard, Row, Parallel bars, Gemini, Flyers wheels and Swing) from the company Entorno Urbano S.L.U (Murcia, Spain), which was located in a private and reserved area for study within the Universidad Católica San Antonio de Murcia, Murcia, Spain.

The TG participants performed a training program using the OFE for 8 weeks, with 2 weekly sessions lasting one hour per session on non-consecutive days. CG participants did not perform any training and were asked to maintain their usual lifestyle. The researchers in charge of conducting the training sessions recorded attendance using Excel software. Average program attendance was 92.75% (min: 78.57%, max: 100%).

The training sessions consisted of resistance circuit training with 11 self-loaded exercises (Table 1) to be performed on the eight OFE machines, following the example from previous research⁵². In the selection of exercises, it was taken into account that there were exercises that involved the dorsal musculature, hip extensors, scapular approximators or abdominal muscles, among others. The execution speed was set by a metronome⁵³. The training program was designed and supervised by Sports Science graduates with Master's degrees in Strength and Conditioning Training, Healthy Aging, and Physical Activity and Health. The training protocol performed is described in Table 2. The training load was regulated by time under tension. A digital metronome was used to set the execution rhythm of the concentric and eccentric phases in each OFE⁵⁴.

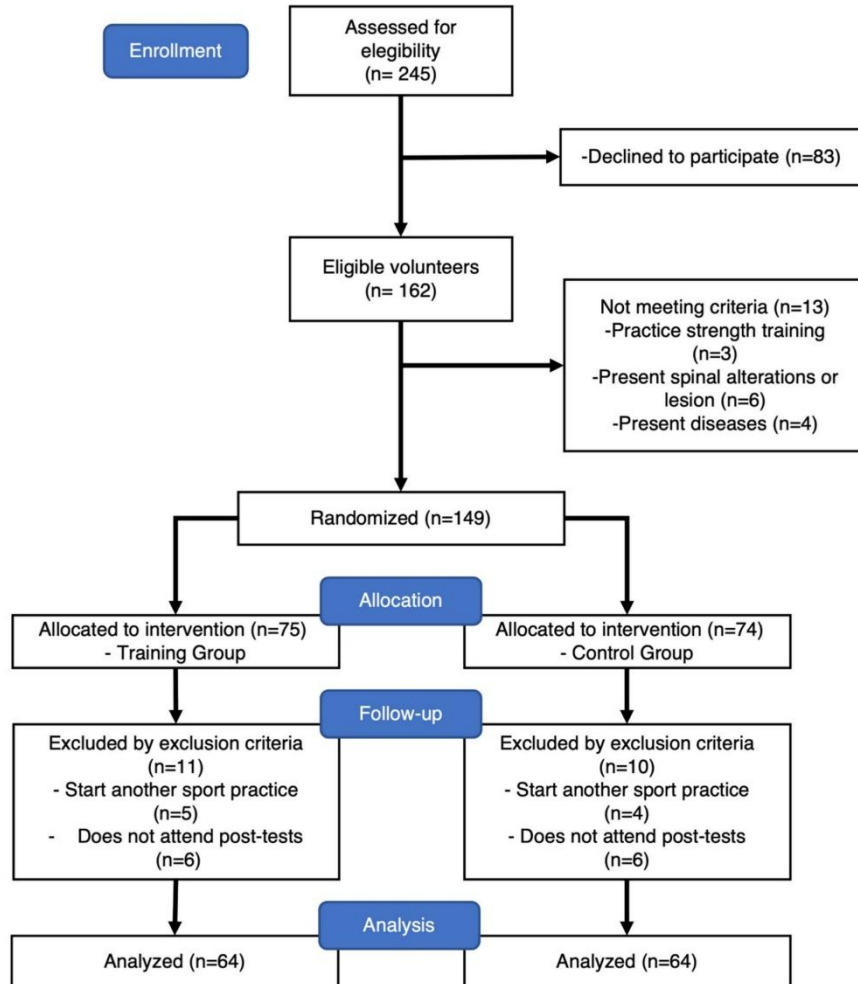


Fig. 1. CONSORT flow diagram. CONSORT flow diagram showing the flow of participants through each stage of the study.

Statistical analysis

After analyzing the normality of the variables using the Kolmogorov–Smirnov test, as well as kurtosis, skewness, and variance, Mauchly’s W-test was used to evaluate the sphericity of the data. Two-way ANOVAs with one-way repeated measures were carried out to analyze inter- and intra-group differences. Partial eta squared (η^2) was used to calculate the effect size and was defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: ≥ 1.2 ; or very large: $ES \geq 2.0$, with an error of $p < 0.05^{59}$. A value of $p < 0.05$ was set to determine statistical significance.

The statistical analysis was performed with the SPSS statistical package (v. 25.0; SPSS Inc., IL).

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Exercise	Method of use	Representation
Bonny rider	Using a supine grip, pull the handle with both hands by flexing the elbow and extending the shoulder	
Shoulder press	On the Gemini machine, taking the grips at a low height, push the handle by elbow extension and shoulder flexion	
Air Walker	Holding and on both platforms, perform hip flexion–extensions keeping the trunk perpendicular. Hold briefly and isometrically at the end of the range of motion	
Tricep dips	On the parallel bars, holding with both hands and starting with the elbow flexed, extend it by overcoming the load of the user's own weight. Adaptation: Triceps push-ups with prone grip sideways to the machine	
Shoulder wheel	On the Flyers Wheels machine, with elbows fully extended and grasping the grips, perform circumduction through shoulder mobility	
Chest press	On the Gemini machine, holding the grips at a middle height, push the handle by elbow extension and shoulder flexion	
Rotator Cuff wheel	On the Flyers wheels machine on the side, support the elbow and take the grip. Perform internal and external rotation	
Calf raise	On the Swing machine, with the knee extended, rest the metatarsal on the lower edge of the platform. Flex and extend the ankle	
Surfboard	Standing on the platform and holding on to the handle, perform from the waist the pendulum movement in the frontal plane. Hold briefly and isometrically at the end of the range of motion	
Continued		

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Exercise	Method of use	Representation
Leg press	On the <i>Swing</i> machine, sitting with feet on the platforms, push through knee extension to overcome the load	
Row	Sitting on the seat, and with the feet in position, pull on the grip by flexing the elbow and externally rotating the shoulder, keeping the trunk perpendicular to the ground	

Table 1. Exercises to be performed in the outdoor fitness equipment circuit.

Week	Sets	T of work / exe (s)	Reps Exe	Concentric/eccentric (repetition/s)	T rest/exe (s)	T rest/set (min)	T session (min)	Total Reps/ session
1	1	30	15	1/1	45	—	13.75	165
2	2	30	15	1/1	30	2	27	330
3	3	30	15	1/1	30	4	43	495
4	3	30	15	1/1	30	4	43	495
5	3	45	15	1/2	30	4	51.25	495
6	3	45	15	1/2	30	4	51.25	495
7	3	45	11	2/2	30	4	51.25	371
8	3	45	11	2/2	30	4	51.25	371

Table 2. Training planning. *Exe* exercise, *Reps* repetitions, *T* time.

Results

Regarding the intergroup baseline differences, Table 3 shows homogeneity in the variables age, gender, marital status, level of education, occupation, who they live with, and number of falls in the last year ($p > 0.05$).

Table 4 shows the pre-post intervention differences in the sagittal spine disposition and pelvic tilt in each of the groups. In the standing position, there was a significant reduction in thoracic kyphosis, lumbar lordosis and pelvic anteversion of the TG after the intervention ($p < 0.001$). In contrast, the CG showed no significant differences in thoracic or lumbar curvatures ($p = 0.863$; $p = 0.053$), although a significant decrease in pelvic tilt ($p = 0.005$) was observed. There were no significant changes in either the TG or CG in the sitting position results, except for a decrease in lumbar lordosis in the TG ($p < 0.001$). These results are shown in Fig. 2.

Table 5 shows the differences between the TG and CG in the pre-post change. The TG showed a significantly greater reduction than the CG in thoracic curvature, lumbar curvature, and pelvic tilt in the standing position ($p = 0.024$ – < 0.001). In the sitting position, a greater reduction in thoracic and lumbar curvature was found in the TG than in the CG ($p = 0.023$ – 0.002). There was no difference in the change that occurred in the pelvic tilt when sitting between groups ($p = 0.607$).

Table 6 shows the differences in pre- and post-test changes between standing and sitting positions. Significantly greater reductions in thoracic and lumbar curvatures and pelvic tilt were observed in the standing position than when sitting ($p < 0.001$).

Discussion

The main objective of the present investigation was to analyze the effect of a resistance training program using OFE on the sagittal spine disposition and pelvic tilt of middle-aged and older adults. The results showed a significant reduction in all curvatures of the sagittal spine disposition in the standing position of the TG after the intervention. In contrast, the CG showed no significant differences in thoracic or lumbar curvatures. In both thoracic and lumbar curvatures, as well as in pelvic tilt, the reduction in the TG was significantly greater than that of the CG.

In accordance with the findings of the current study, previous studies have shown that the systematic performance of multicomponent programs that include general resistance exercises, trunk muscle strengthening, joint mobility exercises, and stretches that target the muscles associated to the trunk, lead to a reduction in sagittal curvatures while in a standing position, following an 8-week training period^{14,25,56}. Similarly, a recent systematic review with meta-analysis concluded that structured physical exercise combining thoracic strength/stabilization, mobility, and flexibility, was an effective intervention for reducing the occurrence of thoracic hyperkyphotic curvatures. However, it suggested that utilizing a multicomponent approach may not be the most optimal strategy for maximizing the desired changes, as the studies reviewed were of low to moderate quality, and more studies on the subject were therefore needed¹⁴.

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	TG (X ± SD or n(%))	CG (X ± SD or n(%))	χ^2/t	p
Age (years)	60.02 ± 7.25	57.83 ± 6.92	0.66	0.511
Gender	Female: 40 (62.5%)	Female: 42 (65.6%)	0.66	0.416
	Male: 24 (37.5%)	Male: 22 (33.4%)		
Marital status	Single: 5 (7.8%)	Single: 3 (4.7%)	5.48	0.242
	Married: 43 (67.2%)	Married: 51 (80.0%)		
	Divorced: 11 (17.2%)	Divorced: 3 (4.7%)		
	Widower: 5 (7.8%)	Widower: 7 (10.9%)		
Level of education	Primary: 13 (20.3%)	Primary: 16 (25.0%)	3.23	0.358
	Secondary: 16 (25.0%)	Secondary: 18 (28.1%)		
	Baccalaureate: 12 (18.8%)	Baccalaureate: 12 (18.8%)		
	University: 23 (35.9%)	University: 19 (29.7%)		
Occupation	Full-time employee: 21 (32.8%)	Full-time employee: 20 (31.3%)	4.34	0.502
	Part-time employee: 7 (10.9%)	Part-time employee: 9 (14.1%)		
	Self-employed: 6 (9.4%)	Self-employed: 9 (14.1%)		
	Unemployed: 7 (10.9%)	Unemployed: 8 (12.5%)		
	Retired: 23 (35.9%)	Retired: 18 (28.1%)		
Who they live with	Partner: 46 (71.9%)	Partner: 49 (76.6%)	1.89	0.594
	Family: 8 (12.5%)	Family: 6 (9.4%)		
	Alone: 10 (15.6%)	Alone: 9 (14.1%)		
Falls in the last year (n)	0.29 ± 0.68	0.30 ± 0.47	-0.09	0.931

Table 3. Comparison of demographic characteristics in training group and control group. TG training group, CG control group.

Variable	Group	Pre-intervention (X ± SD)	Post-intervention (X ± SD)	F	p-value	η^2	Mean dif	95% CI
Standing Thoracic curv. (°)	TG	56.81 ± 5.62	52.05 ± 6.72	47.949	<0.001	0.432	-4.758	-3.385; -6.131
	CG	51.70 ± 8.40	51.88 ± 7.65	0.030	0.863	<0.001	0.180	2.265; -1.904
Standing Lumbar curv. (°)	TG	-25.89 ± 8.46	-20.31 ± 10.56	15.460	<0.001	0.205	5.574	8.409; 2.738
	CG	-26.08 ± 8.47	-25.16 ± 8.96	3.900	0.053	0.058	0.914	1.839; -0.011
Standing Pelvic tilt (°)	TG	11.15 ± 8.15	5.06 ± 5.39	48.318	<0.001	0.434	-6.086	-4.336; -7.836
	CG	8.89 ± 7.09	5.88 ± 5.70	8.601	0.005	0.122	-3.008	-0.958; -5.058
Sitting Thoracic curv. (°)	TG	50.72 ± 6.49	49.44 ± 9.16	3.620	0.062	0.054	-1.281	0.064; -2.627
	CG	46.72 ± 10.61	48.38 ± 9.54	2.342	0.131	0.036	1.664	3.837; -0.509
Sitting Lumbar curv. (°)	TG	-5.80 ± 9.08	0.88 ± 11.22	49.930	<0.001	0.442	6.672	8.559; 4.785
	CG	-5.98 ± 11.09	-4.92 ± 12.11	0.479	0.491	0.008	1.063	4.130; -2.005
Sitting Pelvic tilt (°)	TG	1.40 ± 7.43	0.56 ± 7.06	0.552	0.460	0.009	-0.844	1.426; -3.113
	CG	1.81 ± 7.52	1.75 ± 7.45	0.004	0.951	<0.001	-0.063	1.945; -2.070

Table 4. Intra-group changes of the sagittal spine disposition and pelvic tilt during standing and sitting. CG control group, curv curvature, TG training group. Baseline intergroup difference post-randomization: *p < 0.05; **p < 0.001.

The same trend is found in the older population, where most studies have analyzed the effects of a multicomponent intervention on spinal alignment^{14,56}. However, few studies have demonstrated the effect of a training program based exclusively on guided equipment-based resistance training on the reduction of the sagittal spine disposition in the standing position of middle-aged and older adults²⁸. In that study it was found that a full body work with guided machines can improve thoracic kyphosis, but that on the contrary, a poor selection of guided machines such as core pull and vertical lift exercises and their isometric execution can lead to vertebral fractures²⁸. Another study reported no significant differences, perhaps attributed to the low intensity of the strength program performed with elastic bands²⁷. On the contrary, studies performed on postmenopausal women and men over 45 years of age with a low bone mineral density found that after training similar muscle groups by means of exercises using 80–85% of one maximum repetition, a significant improvement of $-6.7 \pm 8.2^\circ$ and $-2.3 \pm 0.8^\circ$ respectively, of thoracic kyphosis was observed after eight weeks of training^{26,28}. In contrast, they did not report the effect size using eta squared, so it could not be compared. A previous review indicated that the key to generating changes in the sagittal disposition of the thoracic spine could lie on the volume of training and the selection of devices that provide a sufficient load, especially when the trunk musculature was worked in this type of circuit as a synergistic factor with the rest of the exercises^{29,30}. In light of the results of the

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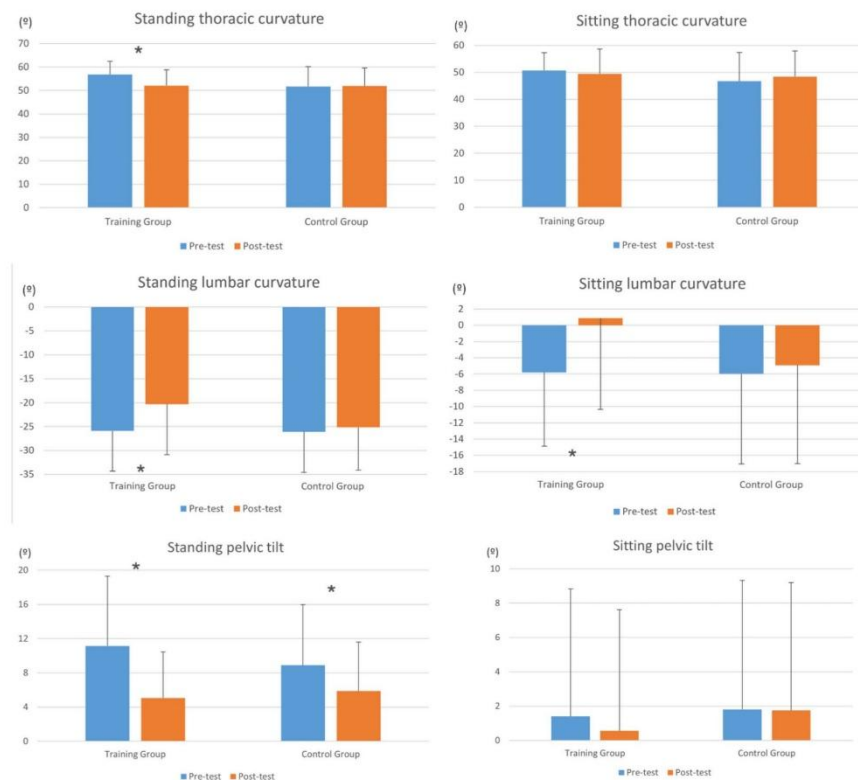


Fig. 2. Sagittal spine disposition and pelvic tilt in standing and sitting positions in both measurements for the training group and the control group. Sagittal spine curvatures and pelvic tilt in the pre-test and the post-test for each group. * indicates that the pre-post differences are $p < 0.05$.

present research, this also seems to be the case with OFE, which could provide a sufficient stimulus to generate adaptations in the spine.

The analysis of the sagittal disposition of the spine in the standing position is essential. It is the most used position especially in older people, due to the consequences it has on aspects such as balance and the probability of falling⁵⁷. It has been observed that an increase linearity can improve people's balance^{57,58}, and therefore, in our case, the improvement in linearity after training could reduce the risk of falling.

The reduction in sagittal curvatures and pelvic tilt in the standing position after resistance training found in the present study could be due to the fact that during the training session, different strengthening exercises were performed, where the trunk musculature was involved as an agonist or synergist, especially the paravertebral muscles, spinal erectors, latissimus dorsi, rhomboids, and the upper back. In addition, the pectoral and shoulder musculature were involved to improve the function of these muscles and to gain a greater range of joint mobility, with these factors associated with a lower thoracic hyperkyphosis^{36,43}. Previous studies have found that trunk musculature exercises are essential for the correction of spinal misalignments^{24,25,38,39}, which in addition to the results presented in this work, demonstrates that the effects of this type of training can also be extrapolated to the older population. Considering the high incidence of hyperkyphosis and hyperlordosis in this population⁸, and their consequences on different areas of health¹⁰, resistance training could be a great resource that could be used by the older population to reduce the incidence of these pathologies¹⁰. In addition, it has been proven that its effect lasts over time; studies in which the strengthening of the spinal extensors was performed, along with other types of exercise, showed that hyperkyphotic women maintained improvements in kyphosis, spinal

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Variable	Group	Diff. Post-pre (X ± SD)	Mean dif	p-value	95% CI (upper; lower limit)	F/Z	ES
Standing Thoracic curv. (°)	TG	-4.76 ± 5.50	4.938	< 0.001	2.49; 7.39	15.938	0.115
	CG	0.18 ± 8.14					
Standing Lumbar curv. (°)	TG	5.57 ± 11.07	4.660	0.002	1.76; 7.55	10.149	0.076
	CG	0.91 ± 3.70					
Standing Pelvic tilt (°)	TG	-6.09 ± 7.00	3.078	0.024	0.41; 5.74	5.222	0.040
	CG	-3.01 ± 8.14					
Sitting Thoracic curv. (°)	TG	-1.28 ± 5.39	2.945	0.023	0.41; 5.48	5.304	0.040
	CG	1.66 ± 8.70					
Sitting Lumbar curv. (°)	TG	6.67 ± 7.55	-5.609	0.002	-9.18; -2.04	9.690	0.071
	CG	1.06 ± 12.28					
Sitting Pelvic tilt (°)	TG	-0.84 ± 9.09	0.781	0.607	-2.22; 3.78	0.265	0.002
	CG	-0.06 ± 8.04					

Table 5. Inter-group changes of the sagittal spine disposition and pelvic tilt during standing and sitting. CG Control Group, *curv* curvature, TG Training Group, ES Effect Size.

Variable	Position	Diff. Post-pre (X ± SD)	Mean dif	p-value	95% CI (upper; lower limit)	t	ES
Thoracic curvature (°)	Standing	-4.76 ± 5.50	-3.48	< 0.001	-4.81; -2.15	-5.23	0.63
	Sitting	-1.28 ± 5.39					
Lumbar curvature. (°)	Standing	5.57 ± 11.07	-5.76	< 0.001	-7.59; -3.92	-6.27	0.12
	Sitting	0.91 ± 3.70					
Pelvic tilt (°)	Standing	-6.09 ± 7.00	-5.24	< 0.001	-8.03; -2.45	-3.75	0.64
	Sitting	-0.84 ± 9.09					

Table 6. Differences in pre-post test changes between standing and sitting positions.

extensor strength, and physical performance one year after the intervention⁵⁹. Another study based on a 3-month intervention using low-load training and elastic bands found that 3 years after the intervention, sagittal spine curvatures did not worsen with ageing⁶⁰. For this reason, training by means of OFE, which in young people has been proven to provide a stimulus similar to low loads^{37,43}, may involve a greater effort in adults, generating an intensity that may result in benefits on the sagittal spine disposition that are maintained over time, with this becoming a topic to be studied in future research.

One of the novelties of the present study was that it assessed the influence of training on the sagittal spine disposition and pelvic tilt also in the sitting position. Sitting is one of the most commonly used positions for spine analysis. It is important to analyze the disposition in this body position in older adults, as this population usually spends long periods sitting, up to 60% of their waking time⁶¹. It has been shown that the sitting position produces greater intradiscal pressure than when standing, and that the loss of spinal linearity further increases the stress on the annulus fibrosus, nucleus pulposus, and cortical bone⁶². Other studies also found that greater lumbar flexion increased intradiscal pressure and antero-posterior compressive and shear stress, which together with prolonged sedation with an inversion of the lumbar spine, increases the capacity for intervertebral flexion due to the viscoelastic deformation of the ligaments of the posterior arch of the vertebrae⁶³. It is for this reason that poor ergonomic positions when sitting can compromise the inversion of the lumbar area to a greater extent, and increase the laxity of the thoracolumbar ligament, which can lead to acute deformations, or chronic ones in the case of being maintained over time, as in the case of the elderly and the long periods of time spent sitting⁶¹. These aspects may influence the health of middle-aged and older adults³⁸. For all of these reasons, previous studies have pointed out that it is necessary to analyze the sagittal spine disposition and pelvic tilt in different positions, beyond the exclusive evaluation in the standing position⁹.

Previous studies showed that OFEs force their users to adopt certain postures with the sagittal spine disposition and pelvic tilt involved during their use³⁵, but this is the first study to verify the effects of their continued use. In the present study, when sitting, a decrease in lumbar lordosis was found in the TG, with a greater disposition in the participants who performed the resistance work as compared to those who did not train. The results found, such as those in the standing position, could be due to the fact that the implementation of a muscle strengthening program reduces the incidence of spinal misalignments^{24,25,56,64}, although this is the first study to demonstrate that this improvement in spinal alignment goes beyond the standing position. In light of these results, resistance training in middle-aged and older adults could improve the sagittal spine disposition in both standing and sitting positions, and may also result in less disc tension⁶⁰ and viscoelastic deformation of the ligaments of the posterior arch of the vertebrae⁶³.

This study also compared the evolution of the curvatures in standing and sitting positions. It was found that the changes produced in the spine through training with OFE were observed, to a greater extent, in the standing position than in the sitting position. The standing position depends to a great extent on muscular

tolerance^{65,66}. Previous studies have suggested that low muscle tolerance of the extensor and stabilizing muscles of the trunk is related to poorer postural hygiene in standing^{65,66}. This could be because, as these muscles fatigue, the latency of muscle activation increases, and fewer bundles of muscle fibers are activated^{66,67}. This leads to less muscular opposition to the effect of gravity, resulting in misalignments from the sagittal spine disposition⁶⁸. Muscle tolerance can be modified with training^{65,68}. More specifically, previous studies have found that resistance training with machines, by generating an activation of the stabilizing muscles of the trunk as synergists maintained over time, increases the muscular tolerance of these muscles⁶⁹. This could lead to greater tolerance of these muscles in their tonic function of maintaining adequate postural hygiene when standing, improving the sagittal spine disposition in this position⁶⁸.

On the contrary, the sitting position usually depends directly on postural hygiene and more specifically the pelvis disposition^{70,71}. Previous studies have suggested that the pelvis tilt is the main factor determining factor for the sagittal spine disposition in a sitting position^{70,71}. This could lead to the tolerance of the extensor muscles of the trunk having less influence on the sagittal spine disposition in this position⁷². Therefore, programs that only work on muscle strengthening, as is the case with the present intervention, could have little effect on the sagittal spine disposition when sitting. And the fact is that, unlike other studies, the focus of this intervention was not the direct work on postural hygiene but the strengthening of the musculature.

Because of all of the above, the improvement of the sagittal spine disposition in sitting position could depend on the ergonomics and postural hygiene of the person rather than on other intrinsic aspects such as muscle tolerance⁷³. On the other hand, the changes could depend more on muscle tolerance in standing^{65,66}. This could explain why changes shown in the present research are reflected to a greater extent in the relaxed standing position. However, in the absence of previous studies that analyzed the effects of strength training on the sagittal spine disposition in both standing and sitting positions in older people, further studies on this topic are needed.

Regarding the clinical relevance of the changes found in the current study, previous studies showed that an improvement of 2.8° in the thoracic curvature angulation was relevant from a clinical point of view⁴⁶. Therefore, since the changes produced by the training were greater than 2.8° of angulation, OFE are deemed as an effective means to achieve an alignment of the sagittal spine disposition. In addition, given that the angle of kyphosis thoracic can increase by 2.6° in three years, 3.9° in four years, and 7° in fifteen years in elders⁷⁴; a reduction close to 5°, as was found in the present investigation, could be considered not only a method of restraining the effects of the passage of time, but also an improvement with respect to the change due to ageing. These improvements could bring benefits such as improved balance, a reduced risk of falling, an improved respiratory capacity, increased mobility, reduced back pain, and reduced pain in the entire back^{1,10–12,57,58}. On the other hand, an intervention of longer duration with OFE could obtain better results, so it would be important to analyze this in future studies.

In summary, it can be observed that OFE can provide a sufficient stimulus to improve spinal curvatures in the standing position, but with a lesser effect in the sitting position after an 8-week intervention. On the other hand, these machines demonstrated their ease-of-use with the elderly population, achieving a high adherence by the participants. In addition, the availability of OFE facilities in multiple parks makes it possible for older people to train on their own, following the training schedule pattern used in the present research, which could improve the sagittal spine disposition in this population in light of the results of the present research. Nevertheless, there are also some barriers, such as the possible poor condition of public OFE due to banditry, as well as the dependence on the weather for their use. In addition, the lack of knowledge on the proper way to train with this type of machine can lead to their inadequate or inefficient use³³.

Regarding the effect size, this study obtained an eta squared of 0.432 in the variable thoracic curvature in relaxed standing position after the intervention performed using OFE. It was found that interventions which consisted of a program of strength, mobility and postural training exercises specifically designed to treat hyperkyphosis in older adults with a similar distribution of training, with two weekly sessions of one hour for 3 months, showed similar value (effect size: 0.419) in the kyphosis variable in standing³⁹. Another study focused on the training of people over 65 performed for 6 months two types of training, one aimed at the extensor muscles of the back and another group that performed an exercise program for the whole body, both using their own body weight and increasing the load with elastic bands or light weights, performing at least a seminal session of between 20 and 30 min⁷⁵. The results contrasted with those presented in this article, since even though the effect size on thoracic kyphosis was greater in the group that did back extensor strengthening protocol with respect to the OFEs (0.62 VS 0.432), in lumbar curvature and pelvic tilt the OFEs obtained a greater or similar effect respectively ES (0.19 Vs 0.205 and 0.06 Vs 0.434, respectively) with an intervention of only 8 weeks.

Despite the novelty of the present research, it is not without limitations. The first limitation of the present study was the sample size, although it was larger than that found in similar studies^{14,27}. In addition, although participation was not limited, a greater number of female volunteers was present, while the male sample was relatively small. Therefore, it was not possible to analyze differences in the effects of resistance training as a function of sex. Therefore, the present results should be extrapolated with caution and may not be extrapolated to populations other than the one presented in this study. In this line, future studies are needed to analyze whether the effect of OFE training on sagittal spine disposition in elders could be influenced by gender. On the other hand, at the time of blinding, due to the design of the study, it could not be applied to the researchers who conducted the training sessions. Another limitation was that the OFE does not allow the external load to be regulated, as they are mostly machines that work with the user's own body weight. Therefore, the evolution of training could not be based on an increase in load, which could be a future line of research. On the other hand, in the current study, the control group maintained their usual lifestyle, and they did not carry out any systematic training. Therefore, there was no traditional machine training group. As a consequence, the design of the present investigation did not analyze whether the effects of OFE training on sagittal spine disposition and pelvic tilt may differ from those achieved with conventional resistance training with gym equipment. This

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precluded determining the strength of the effects of OFE with respect to other machines, but even so, their effect was tested in comparison with the usual life of the control population. This is an important line for future studies.

Based on these limitations and according to the findings of the present study, a recommendation is given to analyze and compare different population groups with special emphasis on differentiation, taking into account the age and the gender of the subjects. It will also be important to perform both standing and seated measurements and to include a comparative analysis. In addition, the use of OFE in interventions where it is combined with other types of exercises, such as stretching or other exercises aimed at improving balance, could enrich our knowledge on OFE. And having a training group with traditional machines in order to compare the strength of the OFE effect could provide more information. Another type of intervention proposed for future research is one in which the load on the OFE can be regulated in order for this factor to be taken into account. Finally, for these interventions, their long-term effects must also be assessed.

Conclusions

After 8 weeks, at a rate of two sessions per week of circuit resistance training with OFE, a better alignment of the thoracic and lumbar spine and pelvic tilt in the standing position was found in middle-aged and older adults. The lumbar curvature in the sitting position was also found to be improved after the training program. These results suggest that programmed training using OFE can be a useful tool for the improvement of the health of older adults, specifically their spine, with only two weekly sessions of circuit resistance training.

The findings of this study highlight the potential for OFE to serve as an accessible and effective tool for improving spinal spine disposition and pelvic tilt among older adults and to reduce age-related spinal misalignments. Communities and policymakers can use these insights to promote health by integrating OFE into public parks and recreational areas, creating safe and well-maintained spaces for older populations to engage in resistance training. Additionally, offering training sessions or reading materials on how to use OFE effectively may address barriers such as a lack of knowledge and ensure proper ergonomic postures.

Data availability

The data presented and/or analysed in this study is available on request from the corresponding authors.

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Author contributions

PJ.M.-P., R.V.-C. and N.G.-G. conducted the research design; T.A.-L., A.E.-G. and N.G.-G. conducted the intervention and data collection; PJ.M.-P., R.V.-C., T.A.-L. and N.G.-G. wrote the main manuscript text; A.E.-G. and N.G.-G. conducted the statistical analysis; PJ.M.-P. and F.E.-R. supervised the above processes and conducted the funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

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ANEXO 15. Estudio 4



Article

Electromyographic Comparison of Traditional Fitness Machines, Outdoor Fitness Equipment Without Load Selectors, and Outdoor Fitness Equipment with Load Selectors in a Seated Chest Press Exercise in Trained Young Men

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Abstract: Outdoor fitness equipment (OFE) are strength training installations comparable to those found in indoor gyms but are located outdoors with greater accessibility. However, the scientific evidence supporting their effectiveness remains limited. The objective of this study was to analyze and compare the electromyographic (EMG) activity of upper limb muscle groups during the use of a traditional seated chest press (SCP) machine, a classic OFE SCP (OFE-SCP), and a new OFE-SCP featuring a load selector system (BIOFIT-SCP). The sample was composed of 34 active young men. EMG activity of five muscle groups was analyzed: the anterior deltoid (AD), the clavicular (CP) and sternal (SP) heads of the pectoralis major, and the lateral (LHTB) and long heads of the triceps brachii (LongHTB), under different intensities. The OFE-SCP showed significantly lower EMG activity compared with the SCP and BIOFIT-SCP in all muscles and phases ($p < 0.001$). Significantly lower EMG activity for the SP in all three phases was found on the BIOFIT-SCP compared with the SCP ($p < 0.001$), but it was significantly higher for the LHTB and AD in the BIOFIT-SCP compared with the SCP during the full and concentric phases ($p < 0.05$ to $p < 0.001$). In conclusion, training with the OFE-SCP generates less EMG activity than traditional machine training, while, in general, BIOFIT-SCP proved effective for strength training comparable to the SCP.

Keywords: outdoor gym; pectoralis major; resistance training; selectorized stack machine; surface EMG; upper limb muscle

1. Introduction

Strength training is becoming increasingly popular in the population thanks to the health benefits it brings to its practitioners [1,2]. Muscle mass gains and increased strength levels are the main objectives of most users who practice it [1,3]. Multiple training methods and tools can be used to train for strength, with guided machines being one of the most widely used [4].

However, in recent years, outdoor fitness equipment (OFE) has become popular as a more accessible alternative to guided machines in a fitness room [5,6]. These are known as sports equipment that are operated in a manner similar to traditional gym

machines, although they are commonly located in public outdoor spaces such as parks [6–8]. Despite the popularity of OFE and the economic investment made for their installation and maintenance, there is some controversy regarding their effectiveness. In this line, while some studies indicate that training with OFE could improve body composition and strength production capacity in older adults [9], as well as improve physical functionality in seniors [10]; other studies indicate that training with this equipment may not be effective in adults and older adults, as a result of the reduced training intensity involved [11,12]. This is because traditional OFE are limited to working with one's own body weight [12], so they do not allow for a controlled intensity progression within training sessions. Therefore, new models are emerging that allow the user to regulate the external load through a system that can be used to increase the weight, similar to that of traditional fitness room guided machines [9,13].

In recent years, machines that allow for pushing-based exercises in a guided manner have increased in popularity and can be found in both traditional guided machine training facilities [14] and OFE [5]. This is because these types of machines have been seen as an alternative to the use of free weights and can provide the same results but with greater safety and less reliance on exercise technique control [14]. Their use is common for both aesthetic purposes and to strengthen the upper body musculature, which is essential for performing daily tasks such as lifting or pushing objects [15].

Along this line, several previous studies have analyzed the efficacy of the seated chest press (SCP) machine by performing a surface electromyographic analysis (EMG) of the activation of the upper limb musculature during its execution [4,16–18]. The choice of the SCP machine was made because it is one of the most popular guided machines for push-work in fitness [19]. These studies have shown that the SCP is an effective machine for activating the main muscle groups involved in these pushing exercises, such as the anterior deltoid, the pectoralis major, and the triceps brachii [16,17,20].

In turn, within most OFE machine lines, SCP machines (OFE-SCP) are also included. However, so far, no studies have been found that analyze the effectiveness of OFE-SCP machines in terms of muscle activity of the a priori involved musculature. Therefore, for practical purposes, it is not known whether this machine could be effective in achieving adaptations in upper limb muscles after training with it. There is, however, a previous study that compared the EMG between traditional leg machines and the OFE leg machine, finding that, in general terms, the OFE showed less activation of the muscles involved in the lower limbs, which could be because it only allows working with one's own weight [13].

Likewise, it has not been empirically proven whether the inclusion of an adjustable external weight in the OFE can improve the effectiveness of SCP machines. Only one previous study compared the EMG readings between a traditional guided leg machine and an OFE that allowed external weight adjustment, finding that at a similar intensity as a percentage of 1RM, a similar activation of the main lower limb musculature occurred, although the activation of the synergist musculature varied slightly because of the biomechanical differences between the exercises performed [13].

Therefore, the main objective of the present investigation was (a) to analyze and compare the EMG recorded in the upper limb muscle groups during the use of a SCP, OFE-SCP, and a push machine belonging to a new line of OFE that allows the external load to be regulated (BIOFIT-SCP); and (b) to determine the differences in the EMG of the upper limb muscle groups at 60 and 75% of 1RM in the SCP and BIOFIT-SCP machines. In relation to the hypothesis, it was proposed that: (a) the EMG of the upper limb musculature will be similar between the machines that allow the external load selection (SCP and BIOFIT-SCP), and activation will be greater in SCP and BIOFIT-SCP machines compared with a machine that only allows working with one's own body weight (OFE-SCP); and (b) the EMG recorded will be greater at 75% of 1RM than in 60% of 1RM in SCP and BIOFIT-SCP machines.

2. Materials and Methods

2.1. Design

This research consisted of a randomized cross-sectional study. The 1RM was calculated on the SCP (Figure 1a) and the new BIOFIT seated chest press (BIOFIT-SCP), which is an OFE that has an external weight selector (Figure 1b). The calculation of the 1RM from each of the machines was done in a different session (session one and session two). Furthermore, the EMG activity of five muscle groups (anterior deltoid (AD), clavicular (CP) and sternal (SP) heads of the pectoralis major, and the lateral (LHTB) and long head of the triceps brachii (LongHTB)) was analyzed on three different types of chest press machines, i.e., SCP, OFE-SCP, and BIOFIT-SCP in another session (session three). In the SCP and BIOFIT-SCP machines, an EMG activity analysis was performed at 60 and 75% of the 1RM, while in the OFE-SCP machine, the analysis was performed with the subject's own body weight. A period of 72 h was given between each of the evaluation sessions of each participant. The study utilized a specific research model, as illustrated in Table S1.

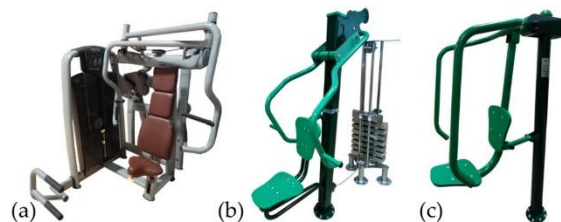


Figure 1. Fitness equipment used. (a) Seated chest press (SCP) (Technogym; Cesena, Italy); (b) outdoor fitness equipment seated chest press with selectorized system (OFE-SCP) (Entorno Urbano, Murcia, Spain); (c) outdoor fitness equipment seated chest press (BIOFIT-SCP) (Entorno Urbano, Murcia, Spain).

The machines selected for this research were: a machine commonly used in the fitness industry, the SCP model (Technogym; Cesena, Italy), with external load adjustment via a selectorized system [3] (Figure 1a); a machine belonging to a new line of OFE called BIOFIT-SCP (Entorno Urbano, Murcia, Spain), which allows the external load adjustment by means of a selectorized system [3], and which is patented (Patent registration for the OFE-SCP at the Spanish Patent and Trademark Office, application number: ES1296848Y; and patent registration for the external load selector, Spanish Patent and Trademark Office application number: P202231017) (Figure 1b); and a classic OFE machine line, corresponding with the same machine model, the Gemini (OFE-SCP) (Entorno Urbano, Murcia, Spain), which uses the user's body weight as the external weight [10] (Figure 1c).

This research was conducted in accordance with the principles outlined in the Declaration of Helsinki and received approval from the institutional ethics committee (Ethical Approval Reference: CE111908). Before starting the study, all volunteers were informed about the different types of tests and voluntarily signed an informed consent form to participate in the present investigation.

2.2. Participants

A methodology utilizing the standard deviation (SD) was employed to determine the sample size [21]. For this analysis, RStudio version 3.15.0 was utilized. The calculations for sample size and statistical power were conducted based on the standard deviation of the variable peak pectoralis major EMG activity during the use of a SCP selectorized plate machine ($SD = 63.82 \mu V$) demonstrated by a sample of physically active young adults ($n = 15$) [18]. An estimated error (d) of $32.30 \mu V$, along with a 95% confidence interval (95%

CI), a statistical power of 95%, and a significance level of 0.05, indicated that a minimum of 34 participants was required for the study.

The study included a total of 34 male participants (mean age = 21.54 ± 1.80 years old; mean stretch stature = 176.62 ± 6.67 cm; mean body mass = 74.27 ± 9.99 kg). The inclusion criteria were: (1) being male, (2) a minimum of 2 years of experience using gym machines for training, along with currently engaging in strength training with these machines at least three times per week, and (3) being within the age range of 19 to 24 years old. The exclusion criteria were: (1) engaging in physical activity within 48 h before the initial session or between assessment sessions [19], (2) any recent injuries to the upper limbs or trunk within the previous 6 months [13], and (3) present a diagnosed muscle abnormalities or joint conditions [13].

2.3. Measurements

2.3.1. Questionnaire

All the participants were asked to complete an ad hoc questionnaire on their socio-demographic characteristics, their experience in strength training, the use of guided machines, and possible injuries and pathologies suffered. This questionnaire was created based on previous studies [13].

2.3.2. Anthropometric Measurements

For the measurement of the anthropometric variables stretch stature and body mass, the indications from the International Society for the Advancement of Kinanthropometry (ISAK) [22] were followed by an accredited ISAK level-2 anthropometrist. An HR001 portable stadiometer (Tanita, Arlington Heights, IL, USA) and a Tanita BC-545N scale (Tanita, Arlington Heights, IL, USA) were used. The variables were measured twice or three times if the difference between the first two was greater than 1%, with the final value being the mean or median, respectively.

2.3.3. Assessment of 1RM

The 1RM was calculated in the SCP and BIOFIT-SCP machines. The OFE-SCP was discarded for this test because it does not have any external weight control system [12]. The order of use of the SCP and BIOFIT-SCP machines to determine the 1RM in each machine was randomized. The protocol recommended by the National Strength and Conditioning Association [23] was utilized for the calculation of 1RM in both machines. The participants performed a warm-up, comprised of a set with an intensity that allowed them to complete between 5 and 10 repetitions. Following a 1 min rest period, the intensity was increased by 10 to 20%, at which point they were required to perform at least three but no more than five repetitions. Following a 2 min rest period, the intensity was increased again by 10 to 20%. At this new intensity, participants were required to complete between two and three repetitions. After this, the intensity was adjusted upward by 10 to 20% for a single repetition attempt. Depending on whether the lift was successfully completed, the load was either increased or decreased by 5 to 10%, repeating this process until the 1RM was identified. A maximum of five attempts at varying intensities were performed, with four minutes between each attempt [23]. A total of 72 h later, the protocol was repeated to determine the 1RM on the other machine, following the prior randomization.

2.3.4. Electromyographic (EMG) Analysis

Seventy-two hours after the second 1RM calculation session, the EMG signal was recorded in AD, CP, SP, LHTB, and LongHTB. The subjects performed, in a randomized order, five repetitions in the SCP machine with intensities of 60 and 75% of 1RM, five repetitions in the BIOFIT-SCP machine with intensities of 60 and 75% of 1RM, and five repetitions in the OFE-SCP machine with their own weight. This protocol followed the procedure of previous studies [13,24]. These intensities were selected for the SCP and

BIOFIT-SCP machines as they are commonly used in different guided machines training methods [13,17].

The electrodes were arranged according to the recommendations from the Surface Electromyography for the Non-invasive Assessment of Muscles (SENIAM) project [25]. The areas where they were placed were shaved and cleaned with 96% alcohol and sterile gauze to avoid possible erroneous signals and reduced skin impedance [26]. The gel electrodes used were placed at a 2 cm center-to-center distance in the longitudinal direction of the muscle fibers [25]. Following the methodology from previous studies, bilateral symmetry was assumed during exercise execution, so all electrodes were located on the right side of the body in a standardized manner [27]. The parts recorded were CP, SP, LHTB, LongHTB, and AD (Figure 2). EMG activity was recorded during exercise using the MuscleLab surface electromyography system (Ergotest Innovation AS, Stathelle, Norway) at a sampling rate of 1500 Hz.

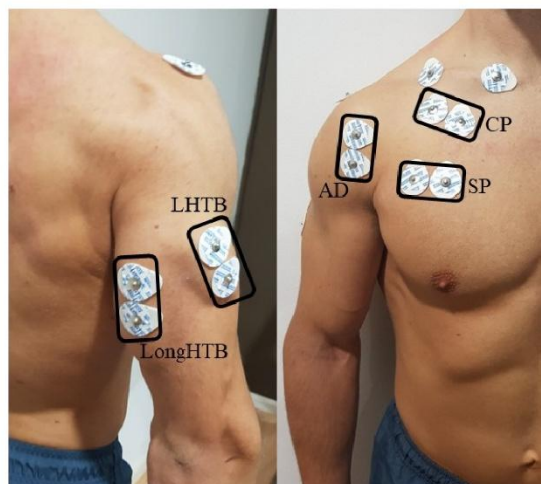


Figure 2. Electrode location on the right arm. AD = anterior deltoid; CP = clavicular pectoralis; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; SP = sternal pectoralis.

2.4. Randomization and Blinding

The sequence of machine usage for the 1RM assessment, the order of machine use for EMG analysis, and the initial 1RM intensity for each machine during EMG analysis were all randomized following the methodology of previous studies [28]. The procedure was conducted by the principal investigator in the presence of external researchers, utilizing a computer-generated random number table. All measurements were carried out following the randomization process.

The researchers who performed the EMG measurements were not involved in the 1RM calculation tests. In the measurements of EMG, the two investigators involved in the data collection were also blinded transversely, where one controlled the exercise execution technique and provided the guidelines for the development of the protocol, while the other focused exclusively on verifying the accuracy of the EMG data recording. This procedure was carried out following previous research [13].

2.5. Procedure

Figure 3 shows the procedures carried out during the three sessions in schematic form, following previous studies [13]. In session one, the volunteers filled out the ad hoc questionnaire, followed by the anthropometric measurements. Subsequently, the essential guidelines for proper exercise execution on each of the three machines (SCP, OFE-SCP, and BIOFIT-SCP) were provided to ensure they were familiar with the required execution technique for each exercise to facilitate accurate data collection. Specifically, they were informed that exercises on the various machines should be performed using a full range of motion, from 90° elbow flexion to full extension. On the SCP machine, the seat was placed at height number 3 so that the height of the seat to the grips was the same as on the BIOFIT-SCP machine.

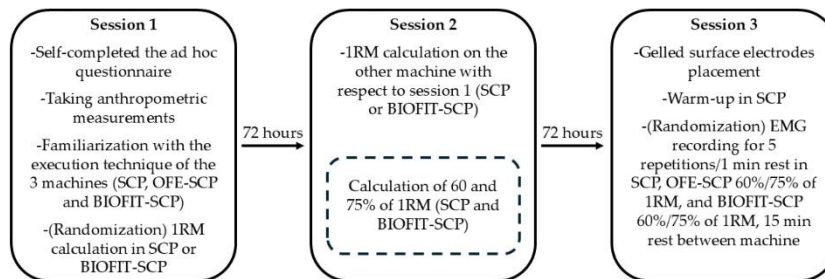


Figure 3. Flow diagram.

Subsequently, participants carried out the 1RM calculation procedure using either the SCP or BIOFIT-SCP machine, with the order of execution assigned randomly. In the second session, the procedure was repeated to assess the 1RM in the other machine. Using the data collected from this procedure, the intensities corresponding to 60% and 75% of the 1RM were subsequently calculated for each participant on both the SCP and BIOFIT-SCP machines.

In the third session, following electrode placement, participants completed a warm-up that included 12 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 8 repetitions at 70% of 1RM, and 2 repetitions at 90% of 1 RM on the SCP, as this was the machine on which the participants had the greatest prior experience, similar to that reported in related studies [13,29]. EMG measurements were then initiated, with the assigned machine (SCP, OFE-SCP, or BIOFIT-SCP) selected randomly. For the SCP and BIOFIT-SCP machines, the intensity level (either 60% or 75% of 1RM) was also randomized. Participants were instructed to perform five repetitions on the initially assigned machine and intensity, maintaining a consistent speed throughout [26]. A 1 min rest was taken between each repetition. After a 15 min rest, the same protocol was repeated on the same machine but using the other intensity. Once the full protocol was completed on the first machine, participants rested for 15 min before beginning the protocol on the second machine [13,26]. In the case of OFE-SCP, a single set of five repetitions was carried out using the participant's body weight, following the same procedure, since the external load could not be modified [6,10]. Rest periods were established based on previous methodologies to prevent fatigue from impacting the results [13,30].

For data analysis, all repetitions that had not been executed correctly from a technical point of view were discarded [13]. The correct execution was considered to involve the following assumptions: (a) that the repetition was performed with a constant rhythm throughout the entire range of motion, without stopping, (b) that a full range of motion from 90° elbow flexion to full extension was involved, and (c) that the buttocks were in

constant contact with the seat and the feet were resting on the floor during the entire execution [31].

The data analysis was conducted using the methodology outlined in a previous study [26]. The first and last repetitions were excluded, and from the remaining three, the repetition with the highest root mean square (RMS) for the primary muscle group involved in the movement, the SP, was chosen, provided it was executed correctly. Data for all the muscles involved were recorded [13]. The data were processed using MuscleLab v10.5.67 software (MuscleLab Ergotest Innovation AS, Norway) by converting the raw amplified EMG signals into RMS values [32]. The RMS variable was measured during the entire repetition, as well as separately for its concentric and eccentric phases, to enable comparisons between machines, consistent with previous studies [33]. A MuscleLab twin-axis electrogoniometer (Ergotest Innovation AS, Stathelle, Norway) was utilized as a movement control variable to distinguish between the concentric and eccentric phases during exercise. The device was positioned on the participant's left arm, near the elbow joint, on the outer side. The distal sensor was aligned with the forearm, while the fixed sensor was aligned with the upper arm [34]. Calibration was performed using a hand-held goniometer set at 90° of elbow flexion while the participant maintained a stable, relaxed position. The point of maximum elbow extension was verified in situ, allowing differentiation of the concentric phase as the data captured from the initial 90° flexion to full elbow extension and the eccentric phase as the data collected from maximum extension back to 90° flexion. The full phase encompassed the analysis of the entire range of motion, beginning and ending at 90° flexion [13].

All measurement sessions were spaced 72 h apart to prevent any potential fatigue effects [35]. All participants were scheduled to attend each session at 8:00 a.m. [13]. All measurements were conducted in the same room, under controlled conditions with a consistent temperature of 20 °C and a stable humidity level of 60%.

2.6. Statistical Analysis

Data analysis was conducted using SPSS software (Version 25; IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test and Mauchly's W-test were applied to assess data normality. Mean values and standard deviations were computed. To compare muscle activation across different machines and intensities, a repeated-measures ANOVA with Bonferroni correction was conducted. To control for Type I error, Bonferroni's correction was applied, setting statistical significance at $p = 0.005$. A threshold of $p < 0.05$ was defined for acceptable error.

3. Results

Table 1 shows the 1RM strength test results for the traditional SCP and BIOFIT-SCP machines.

Table 1. Results of the 1RM strength test.

	1RM	60% 1RM	75% 1RM
SCP (kg)	88.02 ± 20.72	57.21 ± 12.43	66.02 ± 15.54
BIOFIT-SCP (kg)	44.51 ± 15.06	26.71 ± 9.04	33.38 ± 11.30

1RM = one-repetition maximum; BIOFIT-SCP = BIOFIT seated chest press; SCP = traditional seated chest press.

Table 2 shows the mean and standard deviation of the root mean square recorded in each of the muscles analyzed when using the SCP at 60 and 75% of 1RM, the BIOFIT-SCP at 60 and 75% of 1RM, and the OFE-SCP with their own weight. The muscle group that showed a greater RMS was the AD during the concentric phase and the LHTB during the eccentric phase, except for the OFE-SCP, in which the AD muscle group showed a higher activation in both phases. With respect to the complete phase, the highest activations were observed in both the AD and LHTB, with the most notable being those recorded in the BIOFIT-SCP. Regarding the pectoralis, it was observed that CP presented a greater

activation than SP in the two types of OFE (BIOFIT-SCP and OFE-SCP), while in the SCP, the greatest activation was presented by SP. In the triceps, LHTB presented the highest activation in the three machines and during the three phases analyzed compared with the LongHTB.

Table 2. Root mean square recording of the electromyographic signal in the different machines with different 1RM intensities.

	SP (M ± SD)	CP (M ± SD)	LongHTB (M ± SD)	LHTB (M ± SD)	AD (M ± SD)
Complete					
SCP 60%	324.27 ± 173.47	294.47 ± 163.67	223.78 ± 138.17	377.78 ± 167.07	395.81 ± 181.21
SCP 75%	388.32 ± 195.96	348.72 ± 174.16	298.41 ± 153.99	483.80 ± 213.02	475.87 ± 216.16
BIOFIT-SCP 60%	170.39 ± 104.46	294.61 ± 135.61	240.59 ± 76.97	477.74 ± 209.51	491.45 ± 236.06
BIOFIT-SCP 75%	242.52 ± 140.62	345.74 ± 158.54	293.61 ± 92.29	562.39 ± 231.58	565.45 ± 256.92
OFE-SCP	92.13 ± 48.52	131.16 ± 52.86	118.06 ± 43.67	233.81 ± 97.10	282.89 ± 134.02
Concentric					
SCP 60%	405.24 ± 214.63	354.11 ± 174.17	276.03 ± 151.85	449.94 ± 203.93	492.81 ± 221.87
SCP 75%	464.00 ± 231.01	400.29 ± 185.58	357.95 ± 154.14	556.01 ± 241.40	570.43 ± 258.28
BIOFIT-SCP 60%	228.02 ± 137.01	373.41 ± 168.02	314.12 ± 96.52	606.76 ± 249.69	641.30 ± 290.93
BIOFIT-SCP 75%	310.05 ± 174.62	415.49 ± 179.38	362.90 ± 110.13	675.58 ± 269.82	709.09 ± 316.85
OFE-SCP	108.66 ± 58.08	150.04 ± 62.60	141.33 ± 65.01	277.29 ± 140.53	344.46 ± 156.46
Eccentric					
SCP 60%	218.49 ± 130.02	211.61 ± 149.48	160.86 ± 136.70	293.15 ± 152.20	277.87 ± 141.80
SCP 75%	279.58 ± 145.02	271.33 ± 166.85	220.94 ± 163.04	382.85 ± 183.09	355.95 ± 167.18
BIOFIT-SCP 60%	72.34 ± 53.03	171.94 ± 90.23	146.97 ± 63.24	294.86 ± 130.77	275.66 ± 173.07
BIOFIT-SCP 75%	110.50 ± 80.07	216.06 ± 115.29	190.81 ± 81.11	377.98 ± 148.77	340.04 ± 184.52
OFE-SCP	65.07 ± 30.76	103.21 ± 43.51	87.98 ± 35.07	177.75 ± 78.50	196.61 ± 113.77

AD = anterior deltoid; BIOFIT-SCP = BIOFIT seated chest press; CP = clavicular pectoralis; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; OFE-SCP = classic OFE; SCP = seated chest press; SP = sternal pectoralis.

Tables 3–5 and Figure 4 show the differences between machines and between different intensities in the full execution, concentric phase, and eccentric phase, respectively. At the same percentage of 1RM (60% 1RM vs. 60% 1RM, or 75% 1RM vs. 75% 1RM), the SCP presented a significantly greater activation of the SP in the three phases of execution ($p < 0.001$) and of the CP in the eccentric phase during execution at 75% of 1RM ($p < 0.05$) with respect to the RMS recorded in the BIOFIT-SCP. In the other phases and intensities, the CP did not present significant differences ($p > 0.05$). On the other hand, both LHTB ($p < 0.01$) and AD ($p < 0.05$) showed significantly higher activations in the full and concentric phases during the use of the BIOFIT-SCP with respect to the SCP at similar intensities, with no differences in the eccentric phase ($p > 0.05$). No difference in LHTB was found between SCP and BIOFIT-SCP at equal intensity ($p > 0.05$).

Table 3. Differentiation of peak electromyographic activity between different machines and intensities of 1RM during full execution.

Complete Repetition		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	-64.05 ± 7.33 †	153.88 ± 19.24 †	81.75 ± 19.47 **	232.14 ± 25.54 †
	SCP 75%	-	-	217.93 ± 21.28 †	145.80 ± 19.93 †	296.19 ± 29.60 †
	BIOFIT-SCP 60%	-	-	-	-72.13 ± 8.12 †	78.26 ± 15.25 †
	BIOFIT-SCP 75%	-	-	-	-	150.39 ± 21.45 †
	OFE-SCP	-	-	-	-	-
Clavicular pectoralis	SCP 60%	-	-54.25 ± 6.35 †	-0.14 ± 15.64	-51.26 ± 16.01 *	163.31 ± 25.98 †
	SCP 75%	-	-	54.11 ± 17.22 *	2.98 ± 16.46	217.55 ± 27.62 †
	BIOFIT-SCP 60%	-	-	-	-51.12 ± 7.24 †	214.57 ± 25.44 †
	BIOFIT-SCP 75%	-	-	-	-	214.57 ± 25.44 †
	OFE-SCP	-	-	-	-	-

Table 3. Cont.

Complete Repetition		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
LongHTB	SCP 60%	-	$-74.63 \pm 8.21^{\dagger}$	-16.82 ± 21.09	$-69.83 \pm 22.03^*$	$105.71 \pm 21.92^{\dagger}$
	SCP 75%	-	-	57.81 ± 23.17	4.80 ± 23.21	$180.34 \pm 23.96^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-53.01 \pm 5.43^{\dagger}$	$122.53 \pm 10.59^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$175.54 \pm 13.57^{\dagger}$
	OFE-SCP	-	-	-	-	-
LHTB	SCP 60%	-	$-106.02 \pm 12.90^{\dagger}$	$-99.96 \pm 17.90^{\dagger}$	$-184.62 \pm 22.30^{\dagger}$	$143.97 \pm 17.26^{\dagger}$
	SCP 75%	-	-	6.06 ± 17.69	$-78.60 \pm 17.92^{**}$	$249.99 \pm 23.80^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-84.66 \pm 9.72^{\dagger}$	$243.92 \pm 25.18^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$328.58 \pm 28.63^{\dagger}$
	OFE-SCP	-	-	-	-	-
Anterior deltoid	SCP 60%	-	$-80.06 \pm 13.14^{\dagger}$	$-95.64 \pm 25.48^{**}$	$-169.64 \pm 27.18^{\dagger}$	$112.92 \pm 22.97^{\dagger}$
	SCP 75%	-	-	-15.58 ± 25.56	$-89.58 \pm 25.83^*$	$192.98 \pm 28.10^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-74.01 \pm 8.27^{\dagger}$	$208.56 \pm 32.78^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$282.56 \pm 36.24^{\dagger}$
	OFE-SCP	-	-	-	-	-

BIOFIT-SCP = BIOFIT seated chest press; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; OFE-SCP = classic OFE; SCP = seated chest press; * = p value < 0.05; ** = p value < 0.01; $\dagger$ = p value < 0.001.

Table 4. Differentiation of peak electromyographic activity between different machines and 1RM intensities during the concentric phase.

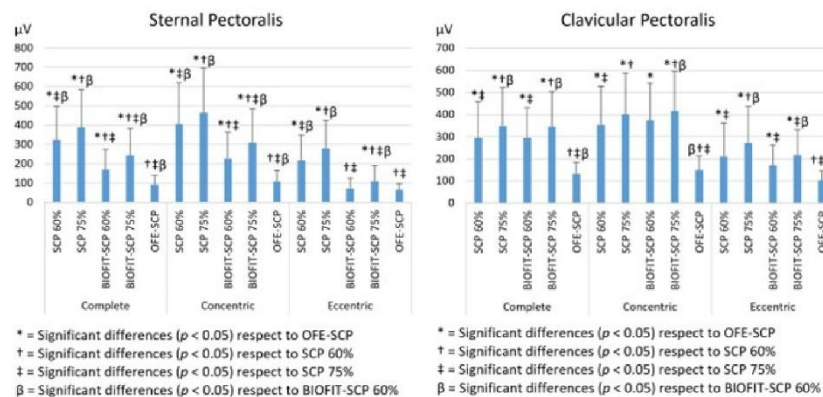
Concentric Phase		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	$-58.76 \pm 8.28^{\dagger}$	$177.22 \pm 23.83^{\dagger}$	$95.19 \pm 24.31^{**}$	$296.58 \pm 32.02^{\dagger}$
	SCP 75%	-	-	$235.98 \pm 24.57^{\dagger}$	$153.95 \pm 23.43^{\dagger}$	$355.34 \pm 35.23^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-82.03 \pm 9.70^{\dagger}$	$119.36 \pm 20.10^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$201.39 \pm 26.60^{\dagger}$
	OFE-SCP	-	-	-	-	-
Clavicular pectoralis	SCP 60%	-	$-46.19 \pm 8.71^{\dagger}$	-19.30 ± 17.99	$-61.38 \pm 18.61^*$	$204.06 \pm 28.57^{\dagger}$
	SCP 75%	-	-	26.88 ± 20.15	-15.20 ± 18.40	$250.25 \pm 30.34^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-42.08 \pm 10.12^{**}$	$223.37 \pm 28.25^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$265.45 \pm 30.12^{\dagger}$
	OFE-SCP	-	-	-	-	-
LongHTB	SCP 60%	-	$-81.92 \pm 10.20^{\dagger}$	-38.09 ± 20.47	$-86.88 \pm 22.06^{**}$	$134.70 \pm 22.52^{\dagger}$
	SCP 75%	-	-	43.82 ± 20.25	-4.96 ± 20.38	$216.61 \pm 21.79^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-48.78 \pm 6.19^{\dagger}$	$172.79 \pm 13.90^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$221.57 \pm 16.35^{\dagger}$
	OFE-SCP	-	-	-	-	-
LHTB	SCP 60%	-	$-106.07 \pm 15.19^{\dagger}$	$-156.82 \pm 19.44^{\dagger}$	$-225.63 \pm 23.34^{\dagger}$	$172.65 \pm 19.97^{\dagger}$
	SCP 75%	-	-	-50.75 ± 19.10	$-119.56 \pm 17.23^{\dagger}$	$278.72 \pm 24.40^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-68.82 \pm 11.79^{\dagger}$	$329.47 \pm 28.76^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$398.29 \pm 31.03^{\dagger}$
	OFE-SCP	-	-	-	-	-
Anterior deltoid	SCP 60%	-	$-77.62 \pm 15.64^{\dagger}$	$-148.49 \pm 29.17^{\dagger}$	$-216.28 \pm 31.89^{\dagger}$	$148.35 \pm 29.06^{\dagger}$
	SCP 75%	-	-	-70.87 ± 29.33	$-138.66 \pm 30.74^{**}$	$225.96 \pm 32.72^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-67.79 \pm 11.52^{\dagger}$	$296.84 \pm 39.90^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$364.62 \pm 43.89^{\dagger}$
	OFE-SCP	-	-	-	-	-

BIOFIT-SCP = BIOFIT seated chest press; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; OFE-SCP = classic OFE; SCP = seated chest press; * = p value < 0.05; ** = p value < 0.01; $\dagger$ = p value < 0.001.

Table 5. Differentiation of peak electromyographic activity between different machines and 1RM intensities during the eccentric phase.

Eccentric Phase		SCP 60%	SCP 75%	BIOFIT-SCP 60%	BIOFIT-SCP 75%	OFE-SCP
Sternal pectoralis	SCP 60%	-	$-61.09 \pm 8.07^{\dagger}$	$146.15 \pm 19.42^{\dagger}$	$107.99 \pm 18.17^{\dagger}$	$153.41 \pm 20.74^{\dagger}$
	SCP 75%	-	-	$207.24 \pm 22.35^{\dagger}$	$169.08 \pm 20.31^{\dagger}$	$214.50 \pm 23.91^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-38.16 \pm 7.55^{\dagger}$	7.26 ± 9.42
	BIOFIT-SCP 75%	-	-	-	-	$45.43 \pm 14.51^*$
	OFE-SCP	-	-	-	-	-
Clavicular pectoralis	SCP 60%	-	$-59.72 \pm 5.72^{\dagger}$	39.68 ± 16.51	-4.45 ± 15.46	$108.40 \pm 22.12^{\dagger}$
	SCP 75%	-	-	$99.39 \pm 18.78^{\dagger}$	$55.27 \pm 16.78^*$	$168.12 \pm 25.04^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-44.12 \pm 8.30^{\dagger}$	$68.73 \pm 11.99^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$112.85 \pm 16.31^{\dagger}$
	OFE-SCP	-	-	-	-	-
LongHTB	SCP 60%	-	$-60.07 \pm 6.92^{\dagger}$	13.90 ± 22.49	-29.94 ± 23.21	$72.89 \pm 23.55^*$
	SCP 75%	-	-	73.97 ± 26.27	30.13 ± 26.70	$132.96 \pm 28.10^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-43.84 \pm 6.50^{\dagger}$	$58.99 \pm 10.72^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$102.83 \pm 12.82^{\dagger}$
	OFE-SCP	-	-	-	-	-
LHTB	SCP 60%	-	$-89.70 \pm 12.84^{\dagger}$	-1.71 ± 18.26	$-84.83 \pm 20.58^{**}$	$115.40 \pm 20.94^{\dagger}$
	SCP 75%	-	-	$87.99 \pm 23.55^{**}$	4.87 ± 24.39	$205.11 \pm 27.57^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-83.12 \pm 10.43^{\dagger}$	$117.11 \pm 17.33^{\dagger}$
	BIOFIT-SCP 75%	-	-	-	-	$200.23 \pm 19.84^{\dagger}$
	OFE-SCP	-	-	-	-	-
Anterior deltoid	SCP 60%	-	$-78.08 \pm 14.19^{\dagger}$	2.21 ± 24.45	-62.17 ± 23.57	$81.26 \pm 21.50^{**}$
	SCP 75%	-	-	$80.30 \pm 25.32^*$	15.91 ± 23.76	$159.35 \pm 23.67^{\dagger}$
	BIOFIT-SCP 60%	-	-	-	$-64.39 \pm 8.76^{\dagger}$	79.05 ± 27.79
	BIOFIT-SCP 75%	-	-	-	-	$143.44 \pm 30.00^{\dagger}$
	OFE-SCP	-	-	-	-	-

BIOFIT-SCP = BIOFIT seated chest press; LHTB = lateral head of the triceps brachii; LongHTB = long head of the triceps brachii; OFE-SCP = classic OFE; SCP = seated chest press; * = p value < 0.05; ** = p value < 0.01; $\dagger$ = p value < 0.001.

**Figure 4.** Cont.

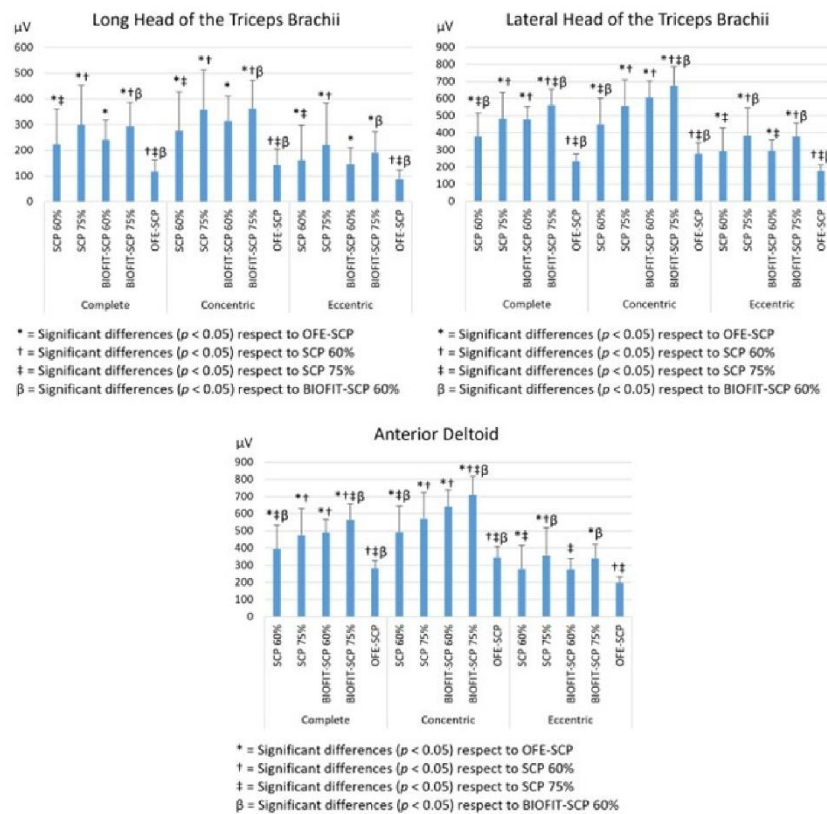


Figure 4. Differentiation of maximal electromyographic activity between different machines and 1RM intensities during the complete, concentric, and eccentric phases in different muscle groups.

When comparing OFE-SCP with SCP and OFE-SCP with BIOFIT-SCP, a significantly lower activation was found in OFE-SCP for all muscle groups in the full execution ($p < 0.001$), concentric ($p < 0.001$) and eccentric phases ($p < 0.05$), except for the SP and AD during the use of BIOFIT-SCP at 60% of 1RM ($p > 0.05$) during the eccentric phase. When comparing each machine (SCP and BIOFIT-SCP) with each of the two different intensities, significant differences were found in all muscle groups and during all the phases ($p < 0.01$).

4. Discussion

The first objective of this research was to analyze and compare the EMG activity of the muscle groups of the upper limbs produced when exercising with the SCP, OFE-SCP, and BIOFIT-SCP machines. Based on previous studies, the performance of exercises involving internal rotation with shoulder abduction and flexion, together with elbow extension, regardless of the biomechanical differences between exercises, involve the same major muscle groups, for example, the pectoral musculature, the AD, or the triceps brachii [20,36]. Other studies have analyzed EMG activity in exercises such as the pec deck, chest press,

or bench press, finding that they all activate the same major muscle groups, despite their technical differences, as they are all upper limb press exercises [19,20,36]. Furthermore, in all the exercises performed on stable guided machines, the stabilizing musculature of the trunk may be less involved, as they rely less on the postural control, compared with exercises with more degrees of freedom of movement, as proven in previous studies that showed significant differences in rectus abdominis activation, being lower during the use of a plate machine compared with a cable-based machine [20]. Based on this, in the present investigation, the decision was made to perform a comparison of the EMG activity with different types of machines, of the muscle groups directly involved in the movement, and not so much of the muscles that could be involved as stabilizers.

A notable finding of this research was that in all three machines, the muscle group that showed a greater RMS was the AD during the concentric phase and the LHTB during the eccentric phase in general. These results coincide with those found in similar works, with the AD being the upper limb muscle that showed the greatest activation during the use of the standing cable press [18]. As for the activation of the LHTB, it could be due to the need for stabilization of the movement, as proven in previous works in which stronger signals were recorded in exercises with a freer movement with respect to chest press machines for this muscle group [20].

An outstanding result of the present investigation was that when comparing EMG activity between machines with the same percentage of intensity, more specifically, SCP and the BIOFIT-SCP, the SP presented a significantly greater EMG signal in all phases recorded in the SCP with respect to the BIOFIT-SCP at the same relative intensities; while the CP showed greater activation in the SCP with respect to the BIOFIT-SCP, but only in the eccentric phase at 75% of the 1RM. This may be due to the fact that the bundles of the SP and CP parts have a recruiting advantage during horizontal glenohumeral flexion and may be due to the better alignment of the muscle fibers with respect to the direction of movement [19,33] during the execution of the SCP, but that the fibers did not maintain the same linearity during the execution of the BIOFIT-SCP. Furthermore, in previous studies where a comparison of the EMG activity of each muscle between exercises and grips was performed, it was observed that a bench press with a grip at 50% of the biacromial distance compared with a grip of 150% of the biacromial distance, presented a lower activation of the SP [4]. Thus, the fibers of the CP and SP were able to collaborate to a greater extent in all phases in the SCP machine with respect to the BIOFIT-SCP machine due to the closest grip in the exercise performed on traditional machines [33]. Given these preliminary results, questions remain as to the importance of fixed or adaptive grip distance during the use of this type of machinery on EMG activation in upper limb pushing exercises.

Continuing with the comparison between the SCP and the BIOFIT-SCP, in the case of the elbow extensors, the LongHTB showed no differences between machines at equal intensity, while the LHTB showed greater activation in the BIOFIT-SCP in the full and concentric phases, both at 60% and 75%, with no differences in the eccentric phase. Studies have justified the participation of the triceps as a synergist muscle in upper limb pushing exercises [20] and thrust exercises that increased its activation by elevating the firing frequency through the inclusion of a backrest that improved the intervention of the main musculature because it reduced the dependence of the stabilizing muscle during the exercise [18]. However, in most studies, the triceps brachii was analyzed uniquely as a muscle group, but locating the electrodes in only one of the muscle bellies [4,16,18,20], with this being the first article to analyze on different machines, the activation of two triceps muscle bellies, the LHTB and the LongHTB. The differences found between both machines in the EMG activity of the triceps brachii musculature may be conditioned by the angulation of the shoulder joint because the BIOFIT-SCP involves a shoulder flexion to a greater extent, while the SCP an adduction flexion, which would condition the EMG involvement of the triceps based on previous studies [19]. Given these promising results, future research is needed to analyze the biomechanics of both machines in order to confirm the results of the present investigation.

Similarly, when comparing EMG activation between SCP and BIOFIT-SCP, the AD showed greater activation in the BIOFIT-SCP in the full and concentric phases, both at 60% and 75%, with no differences in the eccentric phase. This could also be a consequence of the differences in shoulder abduction between the two machines. It has been shown that the AD is involved, to a greater extent, in exercises where the main movement consists of shoulder flexion, compared with those where the main movement is horizontal shoulder adduction [19]. In that sense, the movement in the BIOFIT-SCP is based on a shoulder flexion and an elbow extension with a small shoulder internal rotation, while the movement in the SCP involves a shoulder internal rotation and elbow extension, together with a steady shoulder abduction. Previous results on this issue are contradictory. Thus, while in some studies, it has been found that when comparing different types of plate-loaded chest press and cable-based strength training machines, the AD did not show significant differences between machines [18]. In other studies, it was found that the AD increased its activation during a chest press exercise as the inclination of the bench changed, leading to an increase in shoulder flexion [19]. The differences between studies may be due to the dependence of the execution technique in each of the variants of the exercises because the contribution of a specific muscle will depend on factors such as the specific movement performed in the joint and the anatomical position of the muscle [19]. These promising results indicate the need for future research to analyze the biomechanics of both machines to validate the findings of this study.

Another relevant result of this study was that, when comparing the EMG activity of the BIOFIT-SCP and SCP machines to the OFE-SCP, those machines equipped with an external weight selector showed significantly higher EMG values across all muscle groups, irrespective of the intensity and phase, with only a few exceptions. However, OFE has gained significant popularity in recent years [8,10,12]. No prior studies have been identified that have examined EMG activity using this type of machine, leaving its effectiveness uncertain [37]. However, prior research has indicated that the choice of intensity influences muscle fiber recruitment, thereby affecting the recorded signal [38]. Given that the traditional OFE line only permits exercises using one's own body weight [12], the results of this study may be attributed to the fact that the participants' body weight did not correspond to an intensity near 60% or 75% of their 1RM when using the OFE-SCP. Thus, based on the results of this study, OFE-SCP may have limited effectiveness in generating significant EMG activity [37]. Thus, based on the findings of this study, OFE-SCP may have limited effectiveness in generating significant EMG activity [39], being able to provide only an adequate stimulus in populations with low fitness levels, such as older, deconditioned individuals [40].

Based on the results found in the present investigation, the first hypothesis of this research can be partially accepted, as we found higher EMG activation in SCP and BIOFIT-SCP, as compared to OFE-SCP. However, the second part of the hypothesis, which hypothesized that the EMG activation between the machines with a load selector would be similar (SCP vs. BIOFIT-SCP), has to be rejected, as differences were found in four of the five muscle groups analyzed.

The second aim of this study was to assess the differences in EMG activity of upper limb muscle groups at 60% and 75% of the 1RM using machines that permit intensity adjustment (SCP and BIOFIT-SCP). The results indicated a rise in EMG activity across all the muscle groups analyzed when exercising at 75% of the 1RM compared to 60% of the 1RM for both the full range of motion as well as during the concentric and eccentric phases in the SCP and BIOFIT-SCP. The results are consistent with previous studies, which also reported an increase in EMG activity as intensity increased [41]. This occurs because, at higher intensities, there is an increase in both the recruitment of motor units and their firing frequency [38]. These results support the acceptance of the second hypothesis, as the EMG activity recorded at 75% of 1RM was higher than at 60% of 1RM in both SCP and BIOFIT-SCP conditions.

The primary practical implication of this research is the introduction of a new type of OFE, accessible to both trainers and users, supported by scientific evidence demonstrating its effectiveness in recruiting target muscles similarly to conventional gym equipment. Furthermore, the effectiveness of the OFE was enhanced by implementing an external load selection system. This approach not only ensured adherence to the principle of progressive intensity but also improved the control of training intensity when using these machines.

The main strength of the present research is that it is one of the first studies that has analyzed EMG activity in OFE with a load selector. As studies were not found that compared similar models of indoor and outdoor machines for upper limb exercises, the present study is a pioneer in this aspect. It is also one of the first articles that has analyzed the EMG activation generated by classic OFE, which works with the user's own weight and whose shortcomings have been widely discussed. In addition, this work opens up new avenues of research by suggesting biomechanical and electromyographic analyses of the new patented systems and validities, offering opportunities to optimize their design and functionality in various contexts. In addition, it is one of the few works that includes both the eccentric and concentric phases, as well as the separate analysis of the sternal and clavicular parts of the pectoralis major muscle. In addition to the above, it is the only study that analyzed two of the triceps muscle bellies in guided machines.

Although this study offers a novel approach compared to prior research on the effectiveness of OFE, it is not free from limitations. Firstly, this study did not include an analysis of EMG results for antagonist muscles like the biceps brachii, latissimus dorsi, or other areas such as the lateral deltoid. The location of the electrodes in the back area makes measurement difficult because of the backrest of the machines. On the other hand, future work is encouraged to include an analysis of a larger number of muscle groups whenever possible. A second limitation was that the three machines presented slight variations in execution biomechanics due to the specific mechanics of each device, making direct comparisons between the exercises imprecise. However, it is important to note that studies with an electromyographic component often aim to highlight these biomechanical variations, providing valuable information on how different equipment or variations within the same exercise uniquely affect muscle activation. These comparisons are essential to understanding the nuances of muscle responses. The third limitation of this study was the exclusion of the maximum voluntary contraction test as a variable in the EMG analysis. This work compared the machines using the absolute values recorded. Including this variable could have provided insights into the percentage of activation of each muscle group relative to its maximum during each of the exercises assessed. In addition, it was not possible to calculate the 1RM in the OFE-SCP due to the impossibility of adjusting the load on the machine when working with one's own body weight and mobilizing it with levers. As a final limitation, although the study incorporated an electrogoniometer for elbow joint monitoring during electromyographic signal recording, it did not incorporate a goniometric analysis of the elbow and shoulder joints, which might have provided information on joint angles and their relationship to muscle activation patterns. In addition, it could have provided findings by linking specific joint mechanics to differences in muscle recruitment across machines, such as the difference in angular velocity between shoulder and elbow and whether this changes the data recorded in the interfering muscle groups.

5. Conclusions

It was observed that the EMG activity presented by the current OFE designed to strengthen the upper limb musculature (OFE-SCP) is significantly lower than that of the SCP, a machine commonly used in strength training in fitness centers for the pectoralis, with higher activation in triceps. In contrast, classic OFE, which only allows self-loading work, was found to be less effective than seated chest press machines with external load selectors. Machines with external weight selectors (SCP and BIOFIT-SCP) consistently showed higher EMG activations across all muscle groups compared with self-loading OFE, suggesting that these may be less effective in generating sufficient muscle activation for

hypertrophy and strength adaptations, except for populations with lower fitness levels. Thus, the study supports the idea that OFE with external load selectors represent a valuable tool for strength training, as they show EMG activity levels closer to those of conventional gym equipment. This innovation could improve the applicability of OFE in progressive training programs by allowing controlled intensity adjustments. Additionally, in general terms, a higher intensity implied a greater activation of the involved musculature. This study is a pioneer in the analysis of EMG activation in OFE with external load selection, as it included a separate analysis of the pectoralis major parts and two triceps muscle heads. Future studies should address the limitations of this research, proposing as future lines of research the inclusion of the analysis of antagonist muscles, the goniometric analysis of elbow and shoulder joint angles, as well as taking into account the differentiation of biomechanics of execution between machines, and the maximal voluntary contraction test, in order to know what percentage of activation is generated in each muscle group and to refine the understanding of muscle activation patterns. In addition, it will be necessary to expand the sample to be analyzed, taking into account the female population as well as the older population in future research in order to achieve a greater transfer to the population.

In summary, OFE equipped with external load selectors has the potential to bridge the gap between traditional self-weight OFE and gym-based strength training equipment, offering a controlled approach to muscle activation and adaptation for outdoor fitness applications.

6. Patents

This study presents data on two patents registered by the Spanish Patent and Trade-mark Office: a new machine designed for the outdoor fitness equipment line (code: ES2975897) and an innovative external load selection system of the exercise for this machine (code: ES2975886).

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/s24237740/s1>, Table S1. Research model.

Author Contributions: Conceptualization, T.A.-L., P.J.M.-P., N.G.-G., A.E.-G. and R.V.-C.; methodology, T.A.-L., P.J.M.-P., N.G.-G., A.E.-G. and R.V.-C.; formal analysis, T.A.-L. and N.G.-G.; investigation, T.A.-L. and A.E.-G.; resources, F.E.-R. and R.V.-C.; data curation, T.A.-L., N.G.-G. and A.E.-G.; writing—original draft preparation, T.A.-L. and R.V.-C.; writing—review and editing, T.A.-L., P.J.M.-P., J.A.A., N.G.-G., A.E.-G., F.E.-R. and R.V.-C.; visualization, J.A.A.; supervision, R.V.-C.; project administration, P.J.M.-P. and N.G.-G.; funding acquisition, P.J.M.-P. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of the Universidad Católica de Murcia (Ethical Application Ref: CE111908; 29 November 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy.

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ANEXO 16. Estudio 5



Article

Comparative Electromyographic Analysis in Leg Press of Traditional Fitness Equipment, Traditional Outdoor Fitness Equipment, and a New Model of Outdoor Fitness Equipment in Trained Young Men

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Featured Application: The main practical application of this research is the presentation of a new type of outdoor fitness equipment (OFE) available to both trainers and users, with scientific support regarding its ability to recruit the desired muscles in a similar way to conventional gym machinery. In addition, it was possible to improve the effectiveness of the OFE by including an intensity regulation system, thus allowing the principle of intensity progression to be considered, as well as increasing the control of training intensity in this type of machinery.

Abstract: This study compares the electromyographic activity (EMG) of different muscle groups (rectus femoris, vastus lateralis, biceps femoris, tibialis anterior, and gastrocnemius) of the lower limbs when performing a traditional seated leg press (SLP) with a classic piece of outdoor fitness equipment (OFE-SLP), and with a new OFE leg press that allows the user to adjust the intensity of the exercise by means of a selectorized system (BIOFIT-LP). It was found that the EMG of the OFE-SLP was significantly lower than that of the SLP, but similar activations to those of the SLP were achieved with the BIOFIT-LP. In conclusion, the inclusion of a system to be able to change intensity of the exercise in OFE achieves an EMG activity similar to traditional machinery in trained young men.

Keywords: leg press; lower limb muscle; outdoor gym; resistance training; selectorized stack machine; surface EMG

1. Introduction

The practice of strength training has become popular in recent years, due to the various benefits it brings to the health and functionality of its practitioners [1–3]. Increased strength, hypertrophy, and metabolic improvements are some of the results sought through this type of training [1,4]. To carry this out, multiple resources can be employed, with the use of conventional gym equipment for strength training being one of the most common methods [4–6]. In addition, in recent years, a new line of outdoor fitness equipment (OFE) has emerged, which is sports equipment similar in operation to traditional gym equipment,

but commonly located in outdoor public spaces such as parks [7,8]. It has become easier to find OFE due to its increasing popularity, especially among adults and older people who want to improve their health through outdoor strength training [8,9].

It is known that lower limb muscle mass and strength is a determining factor for multiple aspects such as functional capacity [10] and sports performance [11], with strength training of this part of the body being the quintessential means of skeletal muscle mass gain [12]. This has led to a proliferation of machinery to exercise the lower limb musculature, most of them being multi-joint [11,13,14] and involving different muscle groups [11].

However, prior to the use of any type of machinery for strength work, it is necessary to analyze whether it is effective, i.e., whether it achieves a sufficient activation to generate adaptations of the musculature involved, and whether it is safe, i.e., whether it is not harmful to the musculoskeletal and joint health of the exercise performer [15]. In terms of efficacy, techniques such as surface electromyographic analysis (sEMG) are used to determine the musculature involved in the exercise action. This tool allows the study of muscle function through electrophysiological recording techniques that detect the electrical potentials that cross the membrane of the fibers in the superficial muscles involved in each exercise [16]. In this way, electromyographic activity (EMG) makes it possible to discover the degree of neuromuscular activation during the execution of an exercise for each of the muscle groups that are analyzed, demonstrating its efficacy [17,18].

Many studies have analyzed the EMG of the different muscle groups of the lower limbs in exercises performed with conventional gym equipment [19,20], finding that guided machines such as the traditional seated leg press (SLP) are effective for the work of this muscle group, with activation especially observed in the quadriceps femoris muscles [21]. In this type of equipment, it has also been shown that submitting the subject to a greater intensity generates a greater EMG of the involved muscles [22]. However, despite the popularity of OFE and, in many cases, the large investment of public funds being made for the purchase and installation of these machines in public spaces [8,23], thus far it has only been found that their use can improve both the body composition and strength production capacity in legs and arms in the older population [9], and no studies have analyzed whether OFE is effective, i.e., whether it involves the target musculature at an intensity sufficient to generate structural adaptations in the muscle. On the other hand, classical OFE does not allow progression of the intensity of the exercise, as it allows work exclusively with a self-body mass as the unique intensity of the exercise [24]. Therefore, it would be interesting to also analyze the EMG with a new line of OFE that does allow an increase in intensity of the exercise, with a system similar to that of traditional gym equipment. However, so far there are no data available in this regard either.

Therefore, the objectives of this research were: (a) to analyze and compare the EMG of the lower limb muscle groups when performing an SLP with traditional gym equipment, a leg press machine of classic OFE (OFE-SLP), and a leg press machine belonging to a new line of OFE which allows an adjustment in the intensity of the exercise by means of a selectorized system (BIOFIT-LP); and (b) to determine the differences in the EMG of the lower limb muscle groups at 60 and 75% of the 1RM in the machines that allow the selection of the intensity of the exercise (SLP and BIOFIT-LP).

Regarding the hypotheses of the present investigation, it is hypothesized that: (a) there will be an EMG activation of the lower limb muscles when performing the SLP in the three machines, with the activation being greater when using the machines that allow increasing the intensity of the exercise (SLP and BIOFIT-LP) than in those that only allow working with a self-body weight as the unique intensity of the exercise (OFE-SLP). This could imply that the SLP and BIOFIT-LP machines are more effective for lower limb strength training than the OFE-SLP machine. It is also hypothesized that the activation will be similar between the machines that allow selecting the intensity of the exercise (SLP vs. BIOFIT-LP) for the major muscle groups involved, with differences in some of the synergists. This would imply that both could be equally effective in working on lower limb strength in general, with the differences in EMG activation found between both machines being due to biomechanical

differences in their execution. Because of the above, the machinery to work with could be selected according to the synergists one prefers to involve to a greater extent; and (b) the greater the intensity of the exercise on the machine, the greater the EMG of the muscles involved in both machines. The consequence of this hypothesis, if it is proven, would be that the intensity of the exercise can be used as another variable in the estimation of the training load, regardless of the model, in the machines that allow a selection of the load.

2. Materials and Methods

2.1. Experimental Approach to the Problem

A randomized cross-sectional study was carried out. It consisted of a cross-sectional study where the 1RM was calculated on the seated leg press (SLP) (Figure 1a) and the new BIOFIT leg press (BIOFIT-LP) (Figure 1b) (session 1 and session 2, 72 h apart), and the EMG activity of five muscle groups was analyzed on three different types of leg press machines (session 3, 72 h after session 2). With respect to the machines chosen, one belongs to a line commonly used in the fitness field, more specifically the SLP model (Technogym; Cesena, Italy), which allows adjusting the intensity of the exercise through the use of a selectorized system [4] (Figure 1a); another is from a classic OFE machine line, corresponding with the same machine model, the Columpio (OFE-SLP) (Entorno Urbano, Murcia, Spain) (Figure 1c), which only allows exercising with self-weight as the unique intensity of the exercise (Chow et al., 2021) [25]; and a third one belongs to a new line of OFE, corresponding to the same machine model, called BIOFIT-LP (Entorno Urbano, Murcia, Spain), which allows adjustment of the intensity of the exercise by means of a selectorized system [4], and which is currently under patent registration (patent registration for the OFE-SLP at the Spanish Patent and Trademark Office, application number: ES2975897; and patent registration for the selector of the intensity of the exercise, Spanish Patent and Trademark Office, application number: ES2975886) (Figure 1b). The operation of this machine is based on two handles to be taken on both sides of the body, starting the movement from a 90° flexion of the knee, and from here one must complete a full knee extension against resistance and against gravity (concentric phase). The intensity of the exercise is selected with a selectorized system. On the other hand, the eccentric phase of this exercise goes from knee extension to 90° knee flexion, a descent movement that is done in favor of gravity (eccentric phase). The study utilized a specific research model, as illustrated in Supplementary Table S1.

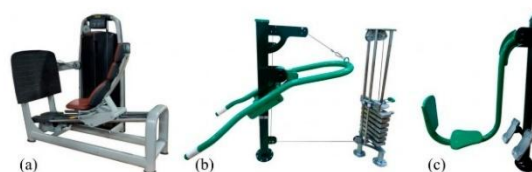


Figure 1. Fitness equipment used. (a) Seated leg press (Technogym; Cesena, Italia); (b) outdoor fitness equipment leg press with selectorized system (Entorno Urbano, Murcia, Spain); (c) outdoor fitness equipment seated leg press (Entorno Urbano, Murcia, Spain).

The study was designed according to the principles of the Declaration of Helsinki and with the prior approval of the institutional ethics committee of the Universidad Católica de Murcia (Ethical Application Ref: CE111908). All participants were informed of the tests to be performed and voluntarily signed a consent form prior to the start of the study.

2.2. Subjects

To calculate the sample size, we used the methodology from previous studies based on the standard deviation (SD) [26]. The Rstudio 3.15.0 software was used for this purpose. Sample size and power were established according to the standard deviation of the peak

EMG activity of the biceps femoris variable ($SD = 49.68 \mu V$) presented by a sample of similar characteristics, composed of young males ($n = 10$) [27]. With an estimated error (d) of $30.79 \mu V$, a confidence interval of 95% (95% CI), a power of 95%, and a significance level of 0.05, the minimum sample needed for conducting the study was 34 subjects.

The sample consisted of 34 males (mean age = 21.54 ± 1.80 years; mean body mass = 74.27 ± 9.99 kg; mean height = 176.62 ± 6.67 cm). The inclusion criteria were: (1) having at least 2 years of experience in training with gym machines and currently training with this methodology at least three times a week; (2) being between 19 and 24 years old; and (3) being male. The exclusion criteria were: (1) having exercised in the 48 h prior to the first session or between evaluation sessions [20]; (2) having suffered any lower extremity, hip, or back injury in the last 6 months; and (3) having any known muscle abnormality or joint disease.

2.3. Measurements

2.3.1. Questionnaire

All participants completed an ad hoc questionnaire to obtain their sociodemographic characteristics, as well as their experience in sports and in the field of machine training and the injuries and pathologies suffered.

2.3.2. Anthropometric Characteristics

Anthropometric measurements of body mass and height were taken following the indications of the International Society for the Advancement of Kinanthropometry (ISAK) [28] by an ISAK-accredited level 2 anthropometrist. A Tanita BC-545N scale (Tanita, Arlington Heights, IL, USA) and an HR001 portable stadiometer (Tanita, Arlington Heights, IL, USA) were used.

2.3.3. Determination of 1RM

The calculation of the 1RM was performed on the SLP and BIOFIT-LP machine, both of which have a selectorized system that allows the intensity of the exercise to be modified. This test was not performed with the OFE-SLP as it does not have any system for increasing the external intensity of the exercise. For the 1RM tests, the order of execution of the SLP and BIOFIT-LP was randomized. In both cases, the protocol proposed by the National Strength and Conditioning Association [29] was employed. Volunteers warmed up by performing a set with an intensity of the exercise with which they could perform between 5 and 10 repetitions. After 1 min of rest, the intensity of the exercise was increased by 10 to 20%, an intensity of the exercise with which the participant had to perform a minimum of 3 and a maximum of 5 repetitions. After 2 min of rest, the intensity of the exercise was increased once again by 10 to 20%. With this intensity of the exercise, the participant had to perform a minimum of 2 and a maximum of 3 repetitions. After this, the intensity of the exercise was increased again by 10 to 20% to perform one repetition, with this weight increased or reduced by 5 and 10%, depending on whether it was lifted correctly or not, until the intensity of the exercise corresponding to the 1RM was obtained. This required a maximum of 5 attempts with different intensity of the exercises, with 4 min of rest between each of them [29]. After 72 h, the same protocol was performed on the other machine, according to the previous randomization performed.

2.3.4. Electromyographic (EMG) Analysis

In a third measurement session, separated by 72 h from the previous session, the EMG of the quadriceps femoris (rectus femoris and vastus lateralis), biceps femoris (long head), tibialis anterior, and gastrocnemius (medial head) muscle groups was measured when performing 5 repetitions on the SLP and BIOFIT-LP machines at 60 and 75% of 1RM. These intensities were chosen as they are commonly used in different training programs, as well as in different EMG studies with guided machinery [30]. The OFE-SLP EMG was analyzed with a single intensity of the exercise allowed (self-weight).

For electrode placement, the different skin areas where the electrodes would be placed were prepared by shaving the hair and cleaning the skin with 96% alcohol and sterile gauze to reduce skin impedance [11,18]. Gelled disposable surface electrodes were used, placed with a 2 cm center-to-center distance, aligned with the longitudinal axis of the muscle fibers, following the methodology from previous studies [31]. The electrodes were placed according to the recommendations of the Surface Electromyography for the Non-invasive Assessment of Muscles (SENIAM) [31] for each of the muscles measured: quadriceps femoris (rectus femoris and vastus lateralis), biceps femoris (long head), tibialis anterior, and gastrocnemius (medial head) (Figure 2). Consistent with similar research, bilateral symmetry was assumed during exercise performance, so electrode placement on the right side of the body was standardized [32]. EMG activity during the exercises was recorded using a surface electromyography system at a sampling rate of 1500 Hz (MuscleLab Ergotest Innovation AS, Stathelle, Norway). The electromyographic signal during the calculation of the 1RM was not taken, since the variability that the EMG signal would present due to fatigue because of the procedure used following the indications of the National Strength and Conditioning Association could lead to bias. In addition, as the sessions in which 1RM was calculated and the sessions in which EMG data were collected were different, variables such as skin impedance or hydration could include more intra-subject variability [11,18]. Therefore, it was decided to measure EMG activation only on the third day, which was the day on which the performance on the different machines was compared.

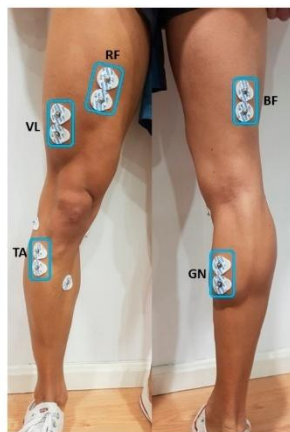


Figure 2. Electrode location on the right leg (**left**—anterior view; **right**—posterior view). RF—rectus femoris, VL—vastus lateralis, BF—biceps femoris, TA—tibialis anterior, GN—gastrocnemius.

Prior to the study, intra-instrument reliability was assessed with a group of 10 training young men by means of test–retest. The tests described above were performed two times in the same session on the same volunteers [33]. It was determined that the electromyographic analysis used in the present study was highly reproducible with a coefficient of variation between 7 and 14% for all muscles on all machines, confirming that the measurement used was sufficiently reproducible.

2.3.5. Determination of Concentric and Eccentric Phases

To differentiate the concentric and eccentric phases during exercise execution, a MuscleLab twin axial electrogoniometer was used (Ergotest Innovation AS, Stathelle, Norway). It was placed on the subject's left leg at the knee joint on the lateral outer side. The distal

gauge of the goniometer was aligned with respect to the leg, while the fixed gauge was aligned with respect to the thigh [34]. It was calibrated using a hand-held goniometer at 90° of knee flexion in stable relaxed sedentation. The point of maximum knee extension was checked in situ, thus differentiating the concentric phase as those data recorded from the beginning at 90° of knee flexion up to that maximum knee extension, and the eccentric phase as the data recorded from maximum knee extension to 90° of knee flexion. The complete phase consisted of the analysis of the entire joint range recorded from 90° of onset to 90° of end [35].

2.4. Randomization and Blinding

Following the methodology from previous studies, the order of execution of the machines for 1RM analysis, of execution of the machines for EMG analysis, and of the 1RM intensity at which each machine was to be started were randomized [27]. This process was performed by the principal investigator in the presence of investigators external to the present research, using a computer-generated random number table.

All measurements were performed after randomization. The investigators who performed the EMGs did not participate in the 1RM calculation tests. In the measurements, the two investigators involved in the data collection were also cross-blinded, whereby one controlled the exercise execution technique and provided the guidelines for the development of the protocol, and the other investigator was only in charge of verifying the correct recording of the EMG data.

2.5. Procedure

Figure 3 shows in schematic form the procedures carried out during the three sessions. In session 1, the volunteers self-completed the ad hoc questionnaire, followed by anthropometric measurements. After this, the key points for the correct execution on each of the three machines (SLP, OFE-SLP, and BIOFIT-LP) were explained to them, in order to familiarize the participants with the expected execution technique on each of them for data collection. More specifically, an indication was given to them that the executions on the different machines should include the full range of motion from a 90° knee flexion to full extension, keeping the sole of the foot fixed in position and maintaining contact with the floor/platform for the duration of the repetition.

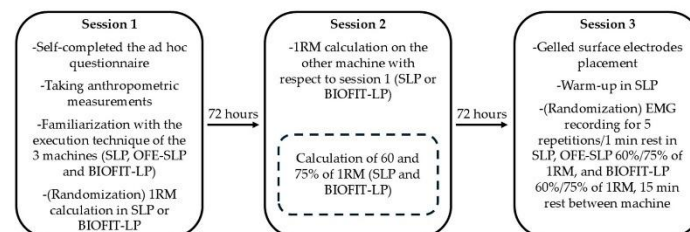


Figure 3. Flow diagram.

After this, the subjects performed the procedure for the calculation of the 1RM on the SLP or BIOFIT-LP machines, whose execution order was established randomly. In session 2, the process was repeated for the other machine. With the data obtained with this procedure, the 60 and 75% values of the 1RM intensity of the exercise were subsequently calculated for each subject on both machines.

In session 3, after electrode placement, participants performed a warm-up set consisting of 12 repetitions at 30% of 1RM, 10 repetitions at 50% of 1RM, 8 repetitions at 70% of 1RM, and 2 repetitions at 90% of 1 RM on the SLP machine, as the subjects had the most previous experience with it, as in similar studies [36]. Subsequently, the EMG

measurement was started in the machine assigned randomly (SLP, OFE-SLP, or BIOFIT-LP). In the case of SLP and BIOFIT-LP machines, the intensity was also randomized (60% or 75% of 1RM). The participant was asked to perform 5 repetitions on the first machine and at the first intensity percentage, with a constant speed throughout [11]. A rest of 1 min was given between each of the repetitions to avoid the effect of fatigue. After 15 min, the same protocol was performed on the same machine, but with the other intensity percentage. After finishing the entire protocol with the first machine, a 15 min rest was provided, after which the protocol was started with the second machine, following the same procedure described above [11]. In the OFE-SLP case, 1 set of 5 repetitions was performed following the procedure previously described with the participant's self-weight, as the participant's intensity of the exercise could not be adjusted [25]. Resting times were set following previous methodologies, so that fatigue would not affect the results [22]. For the analysis of the data, the methodology of a previous study was followed [11]; the first and last repetitions were discarded, and the repetition with the highest root mean square (RMS) of the main muscle group of the movement, the rectus femoris, was selected, provided that it had been performed correctly, with a recording performed in each of the muscles involved [14,37,38].

All measurement sessions were separated by 72 h to avoid possible fatigue effects [37]. All subjects were summoned to all sessions at 8:00 a.m. The measurements were performed in the same room, with a standardized temperature of 20 °C and constant humidity conditions (60%).

2.6. Statistical Analysis

All data were analyzed using the Muscledlab v10.5.67 software (MuscleLab Ergotest Innovation AS, Stathelle, Norway) by passing the raw amplified EMG signal to RMS [14,38]. Thus, the RMS of the peak EMG activity variable was taken in the complete repetition, and in its concentric and eccentric phases, for each muscle group, for the subsequent comparison between machines, as in previous studies [39]. The statistical analysis of the data was performed using SPSS software (Version 25; IBM Corporation, Armonk, NY, USA). The Kolmogorov–Smirnov test and Mauchly's W test were used to evaluate the normality of the data. The mean and standard deviation were calculated. A repeated-measures ANOVA and Bonferroni's correction were used to compare the different muscle activations between machines. To protect against a Type I error, Bonferroni's correction was used to achieve $p = 0.005$ for statistical significance. The effect size was calculated using partial eta-squared (η^2p) for analysis of variance and will be defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: $ES \geq 1.2$; or very large: $ES \geq 2.0$. An error of $p < 0.05$ was established.

3. Results

Table 1 shows the 1RM strength test results for the traditional SLP and BIOFIT-LP machines.

Table 1. Results of the 1RM strength test.

	1RM	60% 1RM	75% 1RM
SLP (kg)	201.51 ± 35.35	120.91 ± 21.21	151.14 ± 26.51
BIOFIT-LP (kg)	56.31 ± 13.72	31.85 ± 11.27	39.82 ± 14.09

1RM = one-repetition maximum; BIOFIT-LP = BIOFIT leg press; SLP = traditional seated leg press.

Table 2 and Figure 4 show the mean and standard deviation of the root mean square recorded in each of the muscles analyzed during the use of the SLP at 60 and 75% of 1RM, the BIOFIT-LP at 60 and 75% of 1RM, and the OFE-SLP with self-weight as intensity of the exercise. In all cases, it was found that the vastus lateralis was the muscle group that attained the greatest activation, followed by the rectus femoris, and thirdly by the tibialis anterior. After these, in the case of SLP and BIOFIT-LP, the next muscle groups with the highest activation were the biceps femoris and gastrocnemius, in that order; while with the OFE-SLP machine, the order of the latter was reversed.

Table 2. Root mean square (μV) recording of the electromyographic signal in the different machines with different 1RM intensities.

	VL (M $\pm$ SD)	RF (M $\pm$ SD)	BF (M $\pm$ SD)	TA (M $\pm$ SD)	GN (M $\pm$ SD)
Complete					
SLP 60%	199.17 $\pm$ 61.46	134.96 $\pm$ 50.57	64.77 $\pm$ 38.23	68.29 $\pm$ 37.92	61.43 $\pm$ 32.66
SLP 75%	241.01 $\pm$ 70.83	176.98 $\pm$ 72.18	82.17 $\pm$ 39.51	88.08 $\pm$ 37.27	77.65 $\pm$ 37.31
BIOFIT-LP 60%	219.09 $\pm$ 69.23	149.25 $\pm$ 64.14	57.51 $\pm$ 33.48	133.69 $\pm$ 63.86	39.48 $\pm$ 20.78
BIOFIT-LP 75%	235.99 $\pm$ 75.52	162.60 $\pm$ 67.85	67.91 $\pm$ 36.25	140.83 $\pm$ 80.50	43.11 $\pm$ 19.41
OFE-SLP	66.89 $\pm$ 26.28	30.00 $\pm$ 17.76	21.22 $\pm$ 10.04	58.18 $\pm$ 55.18	40.18 $\pm$ 26.93
Concentric					
SLP 60%	224.98 $\pm$ 66.44	149.84 $\pm$ 60.63	77.11 $\pm$ 38.01	81.63 $\pm$ 46.72	75.83 $\pm$ 41.86
SLP 75%	274.71 $\pm$ 80.92	206.55 $\pm$ 88.28	95.83 $\pm$ 43.83	100.44 $\pm$ 49.77	90.85 $\pm$ 40.21
BIOFIT-LP 60%	251.12 $\pm$ 80.71	157.21 $\pm$ 74.59	69.14 $\pm$ 30.52	104.11 $\pm$ 51.47	48.86 $\pm$ 26.96
BIOFIT-LP 75%	271.15 $\pm$ 91.27	175.80 $\pm$ 74.10	82.08 $\pm$ 38.36	120.86 $\pm$ 67.79	50.45 $\pm$ 22.55
OFE-SLP	75.26 $\pm$ 32.99	28.09 $\pm$ 13.92	25.92 $\pm$ 12.39	38.52 $\pm$ 31.77	49.11 $\pm$ 32.26
Eccentric					
SLP 60%	168.86 $\pm$ 66.04	114.56 $\pm$ 56.17	39.28 $\pm$ 26.53	49.32 $\pm$ 31.60	41.51 $\pm$ 23.71
SLP 75%	196.34 $\pm$ 70.17	138.85 $\pm$ 60.05	50.26 $\pm$ 27.46	68.47 $\pm$ 30.36	53.89 $\pm$ 27.49
BIOFIT-LP 60%	179.06 $\pm$ 59.44	138.64 $\pm$ 63.56	26.94 $\pm$ 11.79	151.36 $\pm$ 89.07	24.41 $\pm$ 13.89
BIOFIT-LP 75%	187.59 $\pm$ 60.51	146.03 $\pm$ 68.19	32.87 $\pm$ 15.79	153.58 $\pm$ 104.76	30.84 $\pm$ 18.44
OFE-SLP	57.08 $\pm$ 27.61	28.70 $\pm$ 19.35	16.00 $\pm$ 9.36	64.52 $\pm$ 70.84	30.65 $\pm$ 23.68

BF = biceps femoris; BIOFIT-LP = BIOFIT leg press; GN = gastrocnemius; OFE-SLP = classic OFE; RF = rectus femoris; SLP = traditional seated leg press; TA = tibialis anterior; VL = vastus lateralis.

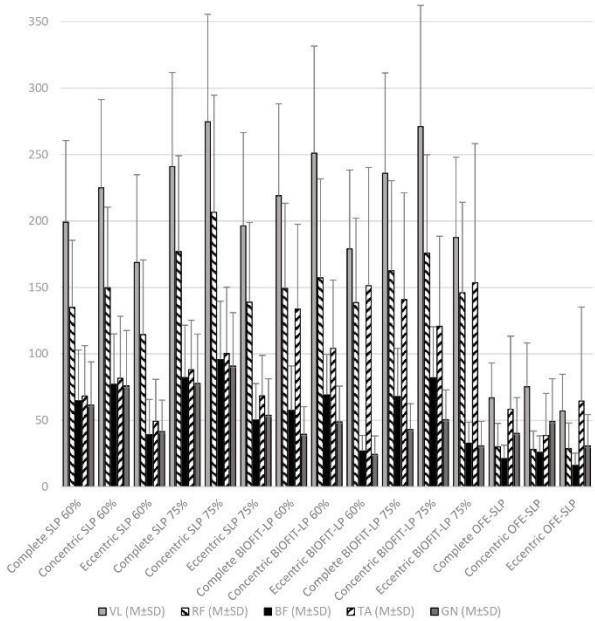


Figure 4. Root mean square (μV) representation of the electromyographic signal in the different machines with different 1RM intensities.

Table 3 shows the differences between machines and between intensity percentages in the complete run, Table 4 shows the concentric phase, and Table 5 shows the eccentric phase. No significant differences were found in the activation of any muscle group when comparing the SLP and BIOFIT-LP machines at the same intensity (60% 1RM vs. 60% 1RM or 75% 1RM vs. 75% 1RM), neither in the complete run, in the concentric phase, nor in the eccentric phase ($p > 0.05$), except for the biceps femoris in the eccentric phase at 75% 1RM, which showed a greater significant activation in SLP as compared to BIOFIT-LP ($ES = 0.60$; moderate effect size; $p < 0.01$); in the tibialis anterior, where there was a greater activation at both intensities in the BIOFIT-LP machine in the full stroke ($ES = 0.53$ – 0.86 ; moderate effect size; $p < 0.01$ – 0.001) and eccentric phase ($ES = 0.69$ – 0.89 ; moderate effect size; $p < 0.001$), but not in the concentric phase ($ES = 0.3$ – 0.5 ; moderate effect size; $p > 0.05$); and gastrocnemius, which showed a greater activation in SLP than in BIOFIT-LP at both intensities and all phases ($ES = 0.68$ – 0.91 ; moderate effect size; $p < 0.05$ – 0.001).

Table 3. Differentiation of peak electromyographic activity (μV) between different machines and intensities of 1RM during a full execution.

Complete Repetition		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	$-41.84 \pm 4.48^{\dagger}$	-19.92 ± 8.38	$-36.82 \pm 9.80^{**}$	$132.285 \pm 8.82^{\dagger}$
	SLP 75%	$41.84 \pm 4.48^{\dagger}$	-	21.91 ± 8.16	5.01 ± 9.93	$174.12 \pm 10.91^{\dagger}$
	BIOFIT-LP 60%	19.92 ± 8.38	-21.91 ± 8.16	-	$-16.90 \pm 5.03^{*}$	$152.21 \pm 9.76^{\dagger}$
	BIOFIT-LP 75%	$36.82 \pm 9.80^{**}$	-5.01 ± 9.93	$16.90 \pm 5.03^{*}$	-	$169.11 \pm 10.82^{\dagger}$
	OFE-SLP	$-132.29 \pm 8.82^{\dagger}$	$-174.12 \pm 10.91^{\dagger}$	$-152.21 \pm 9.76^{\dagger}$	$-169.11 \pm 10.82^{\dagger}$	-
Rectus Femoris	SLP 60%	-	$-42.02 \pm 5.84^{\dagger}$	-14.30 ± 8.89	-27.64 ± 10.59	$104.96 \pm 8.03^{\dagger}$
	SLP 75%	$42.02 \pm 5.84^{\dagger}$	-	27.73 ± 10.74	14.38 ± 13.28	$146.98 \pm 11.84^{\dagger}$
	BIOFIT-LP 60%	14.30 ± 8.89	-27.73 ± 10.74	-	-13.34 ± 6.40	$119.26 \pm 10.04^{\dagger}$
	BIOFIT-LP 75%	27.64 ± 10.59	-14.38 ± 13.28	13.34 ± 6.40	-	$132.60 \pm 10.86^{\dagger}$
	OFE-SLP	$-104.96 \pm 8.03^{\dagger}$	$-146.98 \pm 11.84^{\dagger}$	$-119.26 \pm 10.04^{\dagger}$	$-132.60 \pm 10.86^{\dagger}$	-
Biceps Femoris	SLP 60%	-	$-17.40 \pm 3.41^{\dagger}$	7.25 ± 5.70	-3.14 ± 6.75	$43.55 \pm 6.82^{\dagger}$
	SLP 75%	$17.40 \pm 3.41^{\dagger}$	-	$24.65 \pm 5.99^{**}$	14.26 ± 6.80	$60.94 \pm 6.75^{\dagger}$
	BIOFIT-LP 60%	-7.25 ± 5.70	$-24.65 \pm 5.99^{**}$	-	$-10.39 \pm 2.83^{*}$	$36.29 \pm 6.11^{\dagger}$
	BIOFIT-LP 75%	3.14 ± 6.75	-14.26 ± 6.80	$10.39 \pm 2.83^{*}$	-	$46.68 \pm 6.44^{\dagger}$
	OFE-SLP	$-43.55 \pm 6.82^{\dagger}$	$-60.94 \pm 6.75^{\dagger}$	$-36.29 \pm 6.11^{\dagger}$	$-46.68 \pm 6.44^{\dagger}$	-
Tibialis Anterior	SLP 60%	-	$-19.78 \pm 3.35^{\dagger}$	$-65.39 \pm 10.69^{\dagger}$	$-72.54 \pm 13.67^{\dagger}$	10.12 ± 9.63
	SLP 75%	$19.78 \pm 3.35^{\dagger}$	-	$-45.61 \pm 10.58^{**}$	$-52.75 \pm 12.87^{**}$	29.90 ± 10.28
	BIOFIT-LP 60%	$65.39 \pm 10.69^{\dagger}$	$45.61 \pm 10.58^{**}$	-	-7.14 ± 8.37	$75.51 \pm 10.48^{\dagger}$
	BIOFIT-LP 75%	$72.54 \pm 13.67^{\dagger}$	$52.75 \pm 12.87^{**}$	7.14 ± 8.37	-	$82.65 \pm 14.59^{\dagger}$
	OFE-SLP	-10.12 ± 9.63	-29.90 ± 10.28	$-75.51 \pm 10.48^{\dagger}$	$-82.65 \pm 14.59^{\dagger}$	-
Gastrocnemius	SLP 60%	-	$-16.22 \pm 3.80^{**}$	$21.96 \pm 5.64^{**}$	$18.32 \pm 5.72^{*}$	$21.25 \pm 5.78^{**}$
	SLP 75%	$16.22 \pm 3.80^{**}$	-	$38.17 \pm 5.93^{\dagger}$	$34.54 \pm 6.42^{\dagger}$	$37.46 \pm 6.87^{\dagger}$
	BIOFIT-LP 60%	$-21.96 \pm 5.64^{**}$	$-38.17 \pm 5.93^{\dagger}$	-	-6.63 ± 2.40	-0.71 ± 5.56
	BIOFIT-LP 75%	$-18.32 \pm 5.72^{*}$	$-34.54 \pm 6.42^{\dagger}$	6.63 ± 2.40	-	2.93 ± 5.28
	OFE-SLP	$-21.25 \pm 5.78^{**}$	$-37.46 \pm 6.87^{\dagger}$	0.71 ± 5.56	-2.93 ± 5.28	-

BIOFIT-LP = BIOFIT leg press; OFE-SLP = classic OFE; SLP = seated leg press; * = p value < 0.05 ; ** = p value < 0.01 ; † = p value < 0.001 .

Table 4. Differentiation of peak electromyographic activity (μV) between different machines and 1RM intensities during the concentric phase.

Concentric Phase		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	-49.73 $\pm$ 7.90 [†]	-26.14 $\pm$ 11.69	-46.17 $\pm$ 14.00 *	149.72 $\pm$ 10.35 [†]
	SLP 75%	49.73 $\pm$ 7.90 [†]	-	23.59 $\pm$ 10.00	3.56 $\pm$ 13.40	199.45 $\pm$ 13.69 [†]
	BIOFIT-LP 60%	26.14 $\pm$ 11.69	-23.59 $\pm$ 10.00	-	-20.03 $\pm$ 6.41 *	175.86 $\pm$ 13.00 [†]
	BIOFIT-LP 75%	46.17 $\pm$ 14.00 *	-3.56 $\pm$ 13.40	20.03 $\pm$ 6.41 *	-	195.89 $\pm$ 14.67 [†]
	OFE-SLP	-149.72 $\pm$ 10.35 [†]	-199.45 $\pm$ 13.69 [†]	-175.86 $\pm$ 13.00 [†]	-195.89 $\pm$ 14.67 [†]	-
Rectus Femoris	SLP 60%	-	-56.72 $\pm$ 8.37 [†]	-7.37 $\pm$ 11.84	-25.96 $\pm$ 14.09	121.75 $\pm$ 10.01 [†]
	SLP 75%	56.72 $\pm$ 8.37 [†]	-	49.35 $\pm$ 14.86 *	30.76 $\pm$ 17.70	178.46 $\pm$ 15.09 [†]
	BIOFIT-LP 60%	7.37 $\pm$ 11.84	-49.35 $\pm$ 14.86 *	-	-18.59 $\pm$ 8.61	129.11 $\pm$ 12.32 [†]
	BIOFIT-LP 75%	25.96 $\pm$ 14.09	-30.76 $\pm$ 17.70	18.59 $\pm$ 8.61	-	147.71 $\pm$ 12.19 [†]
	OFE-SLP	-121.75 $\pm$ 10.01 [†]	-178.46 $\pm$ 15.09 [†]	-129.11 $\pm$ 12.32 [†]	-147.71 $\pm$ 12.19 [†]	-
Biceps Femoris	SLP 60%	-	-18.72 $\pm$ 4.68 **	7.97 $\pm$ 7.31	-4.98 $\pm$ 8.76	51.19 $\pm$ 7.05 [†]
	SLP 75%	18.72 $\pm$ 4.68 **	-	26.69 $\pm$ 7.99 *	13.75 $\pm$ 8.90	69.91 $\pm$ 7.75 [†]
	BIOFIT-LP 60%	-7.97 $\pm$ 7.31	-26.69 $\pm$ 7.99 *	-	-12.94 $\pm$ 3.82 *	43.22 $\pm$ 5.72 [†]
	BIOFIT-LP 75%	4.98 $\pm$ 8.76	-13.75 $\pm$ 8.90	12.94 $\pm$ 3.82 *	-	56.17 $\pm$ 7.00 [†]
	OFE-SLP	-51.19 $\pm$ 7.05 [†]	-69.91 $\pm$ 7.75 [†]	-43.22 $\pm$ 5.72 [†]	-56.17 $\pm$ 7.00 [†]	-
Tibialis Anterior	SLP 60%	-	-18.82 $\pm$ 3.91 [†]	-22.49 $\pm$ 9.25	-39.24 $\pm$ 13.60	43.11 $\pm$ 8.65 [†]
	SLP 75%	18.82 $\pm$ 3.91 [†]	-	-3.67 $\pm$ 8.61	-20.42 $\pm$ 12.53	61.92 $\pm$ 9.58 [†]
	BIOFIT-LP 60%	22.49 $\pm$ 9.25	3.67 $\pm$ 8.61	-	-16.75 $\pm$ 9.42	68.59 $\pm$ 9.80 [†]
	BIOFIT-LP 75%	39.24 $\pm$ 13.60	20.42 $\pm$ 12.53	16.75 $\pm$ 9.42	-	82.34 $\pm$ 13.03 [†]
	OFE-SLP	-43.11 $\pm$ 8.65 [†]	-61.92 $\pm$ 9.58 [†]	-68.59 $\pm$ 9.80 [†]	-82.34 $\pm$ 13.03 [†]	-
Gastrocnemius	SLP 60%	-	-15.02 $\pm$ 4.80 *	26.96 $\pm$ 7.39 *	25.38 $\pm$ 7.21 *	26.72 $\pm$ 7.11 **
	SLP 75%	15.02 $\pm$ 4.80 *	-	41.98 $\pm$ 6.56 [†]	40.40 $\pm$ 6.91 [†]	41.74 $\pm$ 6.85 [†]
	BIOFIT-LP 60%	-26.96 $\pm$ 7.39 *	-41.98 $\pm$ 6.56 [†]	-	-1.59 $\pm$ 3.29	-0.24 $\pm$ 6.95
	BIOFIT-LP 75%	-25.38 $\pm$ 7.21 *	-40.40 $\pm$ 6.91 [†]	1.59 $\pm$ 3.29	-	1.35 $\pm$ 6.40
	OFE-SLP	-26.72 $\pm$ 7.11 **	-41.74 $\pm$ 6.85 [†]	0.24 $\pm$ 6.95	-1.35 $\pm$ 6.40	-

BIOFIT-LP = BIOFIT leg press; OFE-SLP = classic OFE; SLP = seated leg press; * = p value < 0.05; ** = p value < 0.01; [†] = p value < 0.001.

When comparing the OFE-SLP with SLP and the OFE-SLP with BIOFIT-LP, a significantly lower activation was found in the OFE-SLP for all muscle groups, in the full stroke, concentric, and eccentric phases (ES = 0.69–1.08; moderate effect size; p < 0.01–0.001), except for the tibialis anterior as compared to SLP for the full stroke and eccentric phase (ES = 0.09–0.42; effect size between small and moderate; p > 0.05); for the gastrocnemius as compared to BIOFIT-LP for the full stroke, concentric phase, and eccentric phase (ES = 0.09–0.2; small effect size; p > 0.05); and for the gastrocnemius as compared to SLP at 60% 1RM in the eccentric phase (ES = 0.25; small effect size; p > 0.05).

When comparing the OFE-SLP with SLP and the OFE-SLP with BIOFIT-LP, a significantly lower activation was found in the OFE-SLP for all muscle groups, in the full stroke, concentric, and eccentric phases (ES = 0.2–0.5 effect size between small and moderate; p < 0.01–0.001), except for the tibialis anterior, as compared to SLP for the full stroke and eccentric phase (ES = 0.14–0.5; effect size between small and moderate; p > 0.05); for the gastrocnemius, as compared to BIOFIT-LP for the full stroke, concentric phase, and eccentric phase (ES = 0.2–0.9; effect size between small and moderate; p > 0.05); and for the gastrocnemius as compared to SLP at 60% 1RM in the eccentric phase (ES = 0.25; small effect size; p > 0.05).

Table 5. Differentiation of peak electromyographic activity (μV) between different machines and 1RM intensities during the eccentric phase.

Eccentric Phase		SLP 60%	SLP 75%	BIOFIT-LP 60%	BIOFIT-LP 75%	OFE-SLP
Vastus Lateralis	SLP 60%	-	-27.48 $\pm$ 3.49 [†]	-10.20 $\pm$ 7.63	-18.73 $\pm$ 7.11	111.79 $\pm$ 8.78 [†]
	SLP 75%	27.48 $\pm$ 3.49 [†]	-	17.28 $\pm$ 8.74	8.75 $\pm$ 8.02	139.27 $\pm$ 9.61 [†]
	BIOFIT-LP 60%	10.20 $\pm$ 7.63	-17.28 $\pm$ 8.74	-	-8.53 $\pm$ 4.09	121.99 $\pm$ 7.41 [†]
	BIOFIT-LP 75%	18.73 $\pm$ 7.11	-8.75 $\pm$ 8.02	8.53 $\pm$ 4.09	-	130.52 $\pm$ 7.55 [†]
	OFE-SLP	-111.79 $\pm$ 8.78 [†]	-139.27 $\pm$ 9.61 [†]	-121.99 $\pm$ 7.41 [†]	-130.52 $\pm$ 7.55 [†]	-
Rectus Femoris	SLP 60%	-	-24.29 $\pm$ 6.01 **	-24.08 $\pm$ 11.08	-31.47 $\pm$ 11.64	85.86 $\pm$ 8.64 [†]
	SLP 75%	24.29 $\pm$ 6.01 **	-	0.21 $\pm$ 10.15	-7.18 $\pm$ 11.48	110.15 $\pm$ 9.63 [†]
	BIOFIT-LP 60%	24.08 $\pm$ 11.08	-0.21 $\pm$ 10.15	-	-7.39 $\pm$ 6.28	109.94 $\pm$ 9.10 [†]
	BIOFIT-LP 75%	31.47 $\pm$ 11.64	7.18 $\pm$ 11.48	7.39 $\pm$ 6.28	-	117.33 $\pm$ 10.15 [†]
	OFE-SLP	-85.86 $\pm$ 8.64 [†]	-110.15 $\pm$ 9.63 [†]	-109.94 $\pm$ 9.10 [†]	-117.33 $\pm$ 10.15 [†]	-
Biceps Femoris	SLP 60%	-	-10.97 $\pm$ 2.70 **	12.35 $\pm$ 4.19	6.41 $\pm$ 4.27	23.28 $\pm$ 4.46 [†]
	SLP 75%	10.97 $\pm$ 2.70 **	-	23.32 $\pm$ 4.43 [†]	17.38 $\pm$ 4.58 **	34.25 $\pm$ 4.15 [†]
	BIOFIT-LP 60%	-12.35 $\pm$ 4.19	-23.32 $\pm$ 4.43 [†]	-	-5.94 $\pm$ 1.51 **	10.94 $\pm$ 2.41 **
	BIOFIT-LP 75%	-6.41 $\pm$ 4.27	-17.38 $\pm$ 4.58 **	5.94 $\pm$ 1.51 **	-	16.87 $\pm$ 2.92 [†]
	OFE-SLP	-23.28 $\pm$ 4.46 [†]	-34.25 $\pm$ 4.15 [†]	-10.94 $\pm$ 2.41 **	-16.87 $\pm$ 2.92 [†]	-
Tibialis Anterior	SLP 60%	-	-19.16 $\pm$ 3.49 [†]	-102.04 $\pm$ 14.40 [†]	-104.26 $\pm$ 16.56 [†]	-15.20 $\pm$ 11.15
	SLP 75%	19.16 $\pm$ 3.49 [†]	-	-82.89 $\pm$ 15.02 [†]	-85.11 $\pm$ 16.76 [†]	3.95 $\pm$ 11.70
	BIOFIT-LP 60%	102.04 $\pm$ 14.40 [†]	82.89 $\pm$ 15.02 [†]	-	-2.22 $\pm$ 9.75	86.84 $\pm$ 13.62 [†]
	BIOFIT-LP 75%	104.26 $\pm$ 16.56 [†]	85.11 $\pm$ 16.76 [†]	2.22 $\pm$ 9.75	-	89.06 $\pm$ 17.86 [†]
	OFE-SLP	15.20 $\pm$ 11.15	-3.95 $\pm$ 11.70	-86.84 $\pm$ 13.62 [†]	-89.06 $\pm$ 17.86 [†]	-
Gastrocnemius	SLP 60%	-	-12.38 $\pm$ 2.44 [†]	17.11 $\pm$ 4.54 **	10.67 $\pm$ 4.70	10.86 $\pm$ 4.30
	SLP 75%	12.38 $\pm$ 2.44 [†]	-	29.48 $\pm$ 5.20 [†]	23.04 $\pm$ 5.32 **	23.24 $\pm$ 4.90 **
	BIOFIT-LP 60%	-17.11 $\pm$ 4.54 **	-29.48 $\pm$ 5.20 [†]	-	-6.44 $\pm$ 1.73 **	-6.25 $\pm$ 3.94
	BIOFIT-LP 75%	-10.67 $\pm$ 4.70	-23.04 $\pm$ 5.32 **	6.44 $\pm$ 1.73 **	-	0.19 $\pm$ 4.47
	OFE-SLP	-10.86 $\pm$ 4.30	-23.24 $\pm$ 4.90 **	6.25 $\pm$ 3.94	-0.19 $\pm$ 4.47	-

BIOFIT-LP = BIOFIT leg press; OFE-SLP = classic OFE; SLP = seated leg press ** = p value < 0.01; [†] = p value < 0.001.

4. Discussion

The main objective of this research was to analyze and compare the EMG activity of the muscle groups of the lower limbs produced during the execution of the leg press with a traditional SLP machine, and OFE-SLP and BIOFIT-LP machines. The results showed that in all three machines, the most activated muscle group was the vastus lateralis, followed by the rectus femoris and tibialis anterior. These results coincide with those found in a similar study, in which a high activation of the vastus lateralis, as well as the rectus femoris and tibialis anterior, was observed during the use of an SLP [22,27,40]. In light of these results, the performance of exercises involving simultaneous ankle and knee extension, regardless of the small biomechanical differences between exercises, involves the same major muscle groups [11]. This corroborates the findings of recent studies, in which muscle electrical activity was analyzed in exercises such as the SLP, the leg press at 45°, and the squat, finding that they all activate the same major muscle groups, despite their differences in execution, as they are all lower limb press exercises [1,11,14]. Furthermore, as all exercises are performed on stable, guided machines, the core musculature may be more involved, as they rely less on the stabilizing musculature, as compared to exercises with free weights [41]. Therefore, it is possible to proceed to the comparison of the machines with each other.

In this regard, an outstanding result of the present investigation was that when comparing machines with the same percentage of intensity, more specifically the EMG activities measured in the SLP and the BIOFIT-LP, similar percentages of activation were found both at 60% and 75% of the 1RM in the main muscle groups involved, in the full stroke, and in the concentric and eccentric phases. No previous studies have analyzed EMG activity in OFE with a selector for the intensity of the exercise, and no studies were found that compared the same model of indoor and outdoor machines, with the present

study being a pioneer in this aspect. However, in other studies comparing indoor machines designed to work the same muscle group, it has been found that at similar percentages of 1RM, the EMG activity of the main muscles involved is similar [19], confirming the results of the present study. In light of these results, it can be affirmed, along the same lines as previous studies, that the amplitude of the EMG was greatly dependent on intensity rather than on the execution technique for both traditional SLP and BIOFIT-LP machines [42].

However, a significantly greater activation was observed in the BIOFIT-LP machine as compared to the SLP machine for the tibialis anterior at both intensities in the full stroke and concentric phase, but not the eccentric one. In contrast, the gastrocnemius showed a greater activation in the SLP as compared to the BIOFIT-LP machine at both intensities and all phases, and the biceps femoris showed greater activation in the SLP at 75% 1RM during the eccentric phase. As observed in several studies, the position of the selector of the intensity of the exercise and ergonomic and biomechanical characteristics of the equipment with respect to the joint levers condition the participation of certain muscle groups [3,43,44]. In this sense, the findings for the SLP machine are in line with what was found in previous studies, where it was shown that in this machine, an increased activation of the biceps femoris and gastrocnemius was generated, especially in the push-off phase [4], due to the co-contraction of these muscle groups, together with the extensor musculature of the knee, to improve the anteroposterior stability of the joint in the angulations of greater instability [4]. Another possible explanation is that the projection of the intensity of the exercise in the SLP falls forward with respect to the base of support and the support of the feet, so that the co-activation of the biceps femoris and gastrocnemius is vital for knee stabilization [4,45]. In contrast, in the BIOFIT-LP machine, the intensity of the exercise projection falls further back with respect to the base of support and foot support, which could favor the activation of the tibialis anterior as a stabilizer of the ankle joint [46]. For all of the above, in general terms, it can be stated that with the new BIOFIT-LP design, an EMG similar to that achieved with the traditional fitness room machines, such as the SLP, could be achieved. Therefore, this new machine design could provide an alternative for effective strength training, albeit outdoors and free of charge, with the advantages that this could have for the health of the population [8]. However, the lack of previous studies analyzing this issue with OFE, and the fact that the studies that have analyzed EMG activity with traditional SLP have included fewer muscle groups than in the present investigation [19], makes it necessary to conduct future research that contrasts the results of the present investigation.

Another relevant result of the present investigation was that when comparing the EMG of the BIOFIT-LP and SLP, with respect to the OFE-SLP, the machines with an external selector for the intensity of the exercise showed significantly higher values in all muscle groups, regardless of the intensity of the exercise, with a few exceptions. Despite the popularity of OFE in recent years [8,24,25], no previous study was found that analyzed EMG activity on this type of machine, so that its efficacy is somewhat uncertain [47]. However, previous studies have pointed out that intensity selection conditions fiber recruitment, and therefore the recorded signal [48,49]. Considering that the classic OFE line only allows working with self-weight [24], the results of the present investigation could be due to the fact that the subjects' own weight did not represent an intensity close to their 60% or 75% of the 1RM during the use of the OFE-SLP. Therefore, in light of the results of the present investigation, the OFE-SLP machine may have a limited efficacy, given the EMG activity it generates [47]. Therefore, it would have little capacity to generate adaptations, especially in terms of hypertrophy in most of the population, as it is lacking the increased muscle recruitment that can potentially provide a more anabolic stimulus [6], being able to only provide a sufficient stimulus in populations with low fitness levels, such as older detrained populations [23].

However, when comparing the EMG of the OFE-SLP with respect to the other two machines, no differences were found in the tibialis anterior as compared to the SLP for the full stroke and eccentric phase; for the gastrocnemius as compared to the BIOFIT-LP for the

full stroke, and the concentric and eccentric phases; and for the gastrocnemius as compared to the SLP at 60% 1RM in the eccentric phase. The discussion of this section is limited, as only one article was found that analyzed the activity of gastrocnemius and tibialis anterior at the same time during the use of guided machines for lower limb training [40], developed on classic fitness center machinery, without including any type of OFE in the analysis. In any case, the function of the gastrocnemius and tibialis anterior muscle groups in this type of exercise is stabilization [4,19], so the lack of differences in EMG between machines may be due to the fact that the execution of these exercises, when performed with guided machines, may not be greatly dependent on these stabilizers [4].

The second objective of this work was to determine the differences in the EMG of the muscle groups of the lower limbs at 60 and 75% of the 1RM on machines that allow selection of the intensity of the exercise (SLP and BIOFIT-LP). The results showed an increase in the EMG activity of all the muscle groups analyzed when performing at an intensity of 75% of the 1RM, compared to 60% of the 1RM, both for the full stroke and for the concentric and eccentric phases in the SLP. The results are in line with those found in previous studies, in which an increase in EMG was found with an increasing intensity [22]. This is because at higher intensities, the recruitment and firing frequency of the recruited motor units increases [48,49].

In contrast, the BIOFIT-LP machine showed significant differences with increasing intensity only in the vastus lateralis for the full stroke and concentric phase, in the biceps femoris for the full stroke and concentric and eccentric phases, and in the gastrocnemius for the eccentric phase. No differences were found in any of the EMG cases on this machine with an increasing intensity for the rectus femoris and tibialis anterior. The fact that differences were found in the posterior musculature in the eccentric phase could be due to the fact that this phase in this exercise is performed in favor of gravity, and the participants were asked to perform it at a controlled speed, so that in the face of an increase in the intensity, it is possible that there would be an increase in EMG activation responsible for slowing down the movement, i.e., posterior musculature [14,50]. In contrast, the concentric phase is performed against gravity, which might require a greater activation of the biceps femoris musculature as the main knee stabilizer [14]. Regarding the vastus lateralis and rectus femoris, the intensity could have been insufficient for the recruitment of more fibers by the rectus femoris, showing differences only in the vastus lateralis. Previous studies have indicated that at high intensity (90% of the 1RM), the vastus lateralis presents greater activations than the rectus femoris [22]. For this same reason, the signal recorded in the tibialis anterior did not present significant differences even when increasing the intensity, indicating the lack of a different stimulus in terms of joint stabilization [46]. Based on the results of the present investigation, in general terms, an increase in the intensity could imply an increase in the recruitment of fibers of the main musculature involved, and therefore, of the adaptations that will be achieved by training with such machinery [22].

The main practical application of this research is that a new line of OFE that has a series of adaptations to be able to adjust the intensity of the exercise achieves similar EMG activations to conventional gym machinery. This information is valuable for both users and trainers, as it demonstrates that this line of machines could be just as effective as conventional machinery to train lower limbs in trained young men. Most of these machines are located in free, open-access facilities, providing an opportunity for the population to do strength work in an economical way and outdoors. The present research also shows that when this type of OFE does not have a system to adjust the intensity of the exercise, a lower EMG intensity is generated, so that the use of OFE that only allows training with one's own body weight could be less effective for strength training than machines that allow an adjustment of the intensity of the exercise in trained young men. Therefore, it would be advisable for public agencies that are investing in the installation of this OFE in public spaces to consider this in order to choose models that have an adjustment of the intensity of the exercise, thus maximizing the population that will be able to train effectively in these facilities. Regarding possible future lines of research, it would be advisable to

analyze other prototypes of OFE to study the effect of different design changes on the EMG presented during their use in the different muscle groups. On the other hand, in the current study, the effect of fatigue was mitigated by allowing a minute of rest between each repetition [51]. Even so, future studies should use one of the various methods of analysis of neuromuscular fatigue [52] as well as zero-crossing of EMG signal [53]. In addition, it would be recommended to replicate the study in a female population or in other age populations to analyze whether the results are replicable in other populations.

Despite the novelty of the present study with respect to previous research on the analysis of the effectiveness of OFE, the present investigation is not without limitations. First, the EMG analysis of the gluteus as a hip extensor was not included due to the location of the electrodes being incompatible with the execution of the exercise on the machines, which is performed from sedentation (SLP and BIOFIT-LP). As a second limitation, the three machines exhibited small variations in the biomechanics of execution, which are conditioned by the mechanism of each of the structures, which makes the comparison between the exercises not exact. As a third limitation, the present study did not include the maximum voluntary contraction test as a variable in the EMG analysis, nor did it record the EMG during the 1RM test, variables that could have helped to differentiate the percentage of activation of each muscle group with respect to its maximum for each of the exercises involved. However, the EMG activation tests on the different machines were performed on the same day, following a randomized order, to eliminate the effect of daily variation on this variable. As a final limitation, although an in situ goniometric analysis was used to differentiate the concentric and eccentric phase, the present study did not include a goniometric analysis of the ankle, knee, and hip joints in the data analysis, which could have helped to discern the origin of the difference in EMG activation between some of the machines.

5. Conclusions

It was observed that the EMG activity presented by the current OFE, designed to strengthen the lower limb musculature (OFE-SLP), is significantly lower than that of the SLP, a machine commonly used in strength training in fitness centers by trained young men. On the other hand, it was found that when some changes in the machine configuration are made to the OFE, and an external intensity of the exercise is included, as performed on the BIOFIT-LP machine, activations similar to those of the SLP are achieved in trained young men. Moreover, in general terms, a higher intensity implied a higher activation of the involved musculature in trained young men. In light of these results, OFE could be considered an alternative to traditional machines for strength work in trained young men.

6. Patents

This research includes data on a new machine for the outdoor fitness equipment line, which is in the process of patenting by the Spanish Patent and Trademark Office (code: ES2975897), as well as of an external intensity of the exercise selection system for this machine (code: ES2975886).

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app14167390/s1>, Table S1: Research model.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy.

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