TESIS DOCTORAL

UCAM
UNIVERSIDAD CATÓLICA DE MURCIA

ESCUELA INTERNACIONAL DE DOCTORADO

Programa de Doctorado en Ciencias del Deporte

Efectos del Entrenamiento Combinado frente al Entrenamiento Selectivo de Resistencia Aeróbica como Terapia Coadyuvante para el Control y Tratamiento de la Hipertensión Arterial en Adultos desde la Atención Primaria

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AUTORIZACIÓN DEL DIRECTOR DE LA TESIS
PARA SU PRESENTACIÓN

La Dra. Dña. Noelia González Gálvez, el Dr. D. Fernando Lozano Ruiz-Poveda y la Dra. Dña María Dolores Masiá Mondéjar como Directores[1] de la Tesis Doctoral titulada "Efectos del Entrenamiento Combinado frente al Entrenamiento Selectivo de Resistencia Aeróbica como Terapia Coadyuvante para el control y Tratamiento de la Hipertensión Arterial en sujetos Adultos desde la Atención Primaria" realizada por Dña. Isabel María López Ruiz en el Programa de Doctorado en Ciencias del Deporte, autorizan su presentación a trámite dado que reúne las condiciones necesarias para su defensa.

Lo que firman, para dar cumplimiento al Real Decreto 99/2011 de 28 de enero, en Murcia a 11 de octubre de 2025.

Dra. Dña. Noelia González Gálvez

Dr. D. Fernando Lozano Ruiz-Poveda

Dra. Dña. María Dolores Masiá Mondéjar

[1] Si la Tesis está dirigida por más de un Director tienen que constar y firmar ambos.

RESUMEN

Estudios epidemiológicos recientes siguen posicionando la enfermedad cardiovascular como causa principal de muerte en el mundo. Estos estudios también sitúan la hipertensión arterial (HTA) como principal factor de riesgo modificable de causa de muerte cardiovascular a nivel mundial, siendo esta responsable de más de 10 millones de muertes al año.

La HTA se considera un trastorno crónico con una etiología multifactorial en la que los niveles de presión arterial se mantienen elevados permanentemente. Se puede diferenciar entre hipertensión primaria y secundaria, siendo la más frecuente la esencial o primaria, que corresponde aproximadamente al 90-95% de los casos. Esta presenta una serie de factores de riesgo de origen biológico o no modificables y de naturaleza ambiental o modificables; estos últimos asociados al estilo de vida. Más del 50% de las personas con HTA presentan sobrepeso-obesidad, hipercolesterolemia, dislipemia, resistencia a la insulina o diabetes tipo II, además son sedentarias y/o llevan una mala alimentación. Las guías europeas de cardiología e hipertensión consideran hablar de HTA cuando, en consulta, los niveles de presión arterial sistólica (PAS) sean iguales o superiores a 140 mmHg y/o los niveles de presión arterial diastólica (PAD) sean iguales o superiores a 90 mmHg. Por otro lado, las guías americanas establecen los niveles de HTA por encima de 130 mmHg para la PAS y de 80 mmHg para la PAD.

Las intervenciones terapéuticas no farmacológicas, que implican cambios de hábitos y de conductas, cada vez están adquiriendo más fuerza en el ámbito clínico. Dentro de esas intervenciones, una de las más importantes para la mejora de la salud cardiometabólica es el ejercicio físico realizado con regularidad y mantenido en el tiempo. Existe suficiente evidencia científica para poder afirmar que el ejercicio físico actúa como fármaco capaz de prevenir y tratar numerosas enfermedades no transmisibles de la sociedad actual, entre las que se encuentra la HTA.

Las guías clínicas de cardiología e hipertensión contienen apartados exclusivos en los que se exponen las recomendaciones de ejercicio físico para este grupo de población. El entrenamiento de resistencia aeróbica es la modalidad principal, aconsejan realizarlo entre 150-300 min/semana (5-7 días/semana) si la

intensidad es moderada, y alternarlo con 75-150 min/semana (2-3 días/semana) si la intensidad es vigorosa. Estas guías recomiendan implementar el entrenamiento de resistencia aeróbica con el entrenamiento de fuerza al menos 2 días/semana, sin profundizar mucho más en su prescripción. Ambas modalidades de entrenamiento han mostrado reducciones significativas de los niveles de presión arterial; sin embargo, en estas recomendaciones no se hace referencia al entrenamiento combinado de ambas modalidades en la misma sesión. Existen trabajos con intervenciones de entrenamiento combinado en este grupo de población y cuyos resultados han sido positivos, consiguiendo reducciones significativas de presión arterial en adultos con HTA. Pese a estos resultados, son necesarias nuevas investigaciones al respecto para poder establecer relaciones dosis-respuesta, debido a la heterogeneidad de los protocolos utilizados. En los últimos años, el entrenamiento interválico de alta intensidad (HIIT) ha ganado popularidad en el ámbito clínico. Esta modalidad de ejercicio ha mostrado grandes beneficios para la salud cardiometabólica y, concretamente, sobre los niveles de presión arterial.

La programación del entrenamiento, y más concretamente del entrenamiento de fuerza, es una tarea compleja. Comúnmente, en la literatura al respecto, se ha determinado la intensidad de trabajo en base al valor de una repetición máxima (1RM), considerado el gold standard, o de un número máximo de repeticiones (xRM); ambos métodos poco precisos, para una correcta dosificación del esfuerzo, e incluso lesivos, cuando el sujeto es principiante o cuenta con poca experiencia en la práctica de ejercicio físico. Para hacer frente a estas limitaciones, se ha propuesto la velocidad de ejecución, herramienta a través de la cual se puede programar de forma objetiva y con la máxima precisión posible el grado de esfuerzo del entrenamiento de fuerza.

En base a lo expuesto, los objetivos de la presente tesis doctoral fueron:

1) Evaluar el impacto del entrenamiento multicomponente en la presión arterial de adultos con HTA y establecer una relación dosis-respuesta.

2) Comparar el efecto de dos programas de ejercicio físico diferentes (GE1, fuerza combinado con entrenamiento continuo de moderada intensidad; GE2, entrenamiento continuo de moderada intensidad) y un grupo control sobre los biomarcadores sanguíneos y metabólicos, la composición corporal y la condición física en adultos con HTA.

3) Comparar los efectos de tres programas de ejercicio físico diferentes (GE1, entrenamiento continuo de moderada intensidad; GE2, entrenamiento de fuerza combinado con entrenamiento continuo de moderada intensidad; GE3, entrenamiento de fuerza combinado con HIIT) y un grupo control sobre los biomarcadores sanguíneos y metabólicos, la composición corporal y la condición física en adultos con HTA.

4) Proporcionar a los profesionales del ámbito de la salud, médicos cardiólogos, cardiólogos del deporte, médicos de atención primaria y CAFyD (Graduados en Ciencias de la Actividad Física y del Deporte), recomendaciones sobre como prescribir de forma precisa, adecuada y segura un programa de ejercicio en adultos con HTA.

En torno a las cuestiones planteadas en los objetivos, en la presente tesis doctoral se han llevado a cabo 4 estudios:

1) Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials.

2) Concurrent training based on an individual load-velocity ratio assessment as a better alternative to continuous endurance training to improve hypertension.

3) Moderate intensity continuous training, combined moderate-intensity continuous training vs combined high-intensity interval training in adults with hypertension: Randomized controlled trial.

4) Diseño de un programa de entrenamiento combinado individualizado para adultos con hipertensión arterial.

En el estudio 1 se realizó una revisión sistemática y meta-análisis en la que se examinó los efectos de un programa de intervención con entrenamiento multicomponente sobre los niveles de presión arterial en adultos con HTA. Para ello, se siguieron las directrices de la declaración PRISMA y se registró en PROSPERO. Se incluyeron nueve estudios, tras una búsqueda bibliográfica en diferentes bases de datos, PubMed, Web of Science, Cochrane y EBSCO. Se consideraron para la inclusión únicamente ensayos controlados aleatorizados que realizaron intervenciones con entrenamiento multicomponente en adultos con HTA. Además, se realizó una evaluación de la calidad mediante la escala PEDro y se utilizó un modelo de efectos aleatorios para todos los análisis.

En los estudios 2 y 3 se presentaron dos trabajos originales resultantes del proyecto Corazón y Salud. Se llevó a cabo un ensayo clínico aleatorizado, simple ciego, longitudinal y prospectivo con varias ramas de estudio simultáneas. El periodo de intervención fue de 12 semanas con una frecuencia de entrenamiento de 2 días por semana y una duración de 60 minutos por sesión de entrenamiento.

Para el estudio 2, se contó con 75 voluntarios (36 mujeres y 39 hombres), con una edad media de 54 años, todos ellos con HTA diagnosticada y sedentarios, nunca antes habían realizado ejercicio físico o, al menos, durante los últimos 12 meses. La muestra fue distribuida aleatoriamente en dos grupos de intervención. El grupo experimental (GE) 1 realizó un programa de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con MICT (n=25). El GE2 llevo a cabo un MICT (n=25). Mientras que el grupo control (GC) siguió su estilo de vida sin modificaciones (n=25).

Para el estudio 3, se contó con 100 voluntarios, 51 mujeres y 49 hombres, con una edad media de 54 años, todos ellos con HTA diagnosticada y sedentarios. La muestra fue distribuida aleatoriamente en tres grupos de intervención. El GE1 realizó MICT (n=25); el GE2 llevo a cabo un entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con MICT (n=24); el GE3 siguió un entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con HIIT (n=23). El GC siguió su estilo de vida sin modificaciones(n=25).

Todos los participantes fueron evaluados al inicio y al final de la intervención de las siguientes variables dependientes: PAS, PAD, y presión arterial media (PAM), presión de pulso (PP), doble producto (DP), frecuencia cardiaca máxima (FCmáx), frecuencia cardiaca basal (FCbasal), peso, masa musculoesquelética, masa grasa, área de grasa visceral, perfil lipídico, colesterol total (CT), HDL, LDL, triglicéridos (TG), glucosa, fuerza máxima y capacidad cardiorrespiratoria.

En el estudio 4 se realizó un documento con recomendaciones y protocolos para la prescripción individualizada de ejercicio físico en población adulta con HTA. Este documento trata de proporcionar una guía a los profesionales de la salud para poder diseñar correctamente un programa de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con entrenamiento continuo de moderada intensidad, con la finalidad de mejorar la salud cardiometabólica en este tipo de población y prevenir futuros

eventos cardiovasculares adversos. En el documento se facilitan las pautas para dosificar, de la manera más precisa y segura posible, la carga o estímulo de trabajo para ambas modalidades de entrenamiento.

Como conclusiones, el estudio 1 indica que los programas de entrenamiento multicomponente mejoraron significativamente los niveles de PAS y PAD en los adultos con HTA. Los mayores beneficios se encontraron en programas con una duración superior a 14 semanas, 3 sesiones/semana de 60 min y con intensidades en torno al 75% de la FC de reserva para el entrenamiento de resistencia aeróbica, y superior al 75% de 1 RM, con 10 o menos repeticiones por serie, para en entrenamiento de fuerza. Los estudios 2 y 3 revelan que realizar un programa de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con un entrenamiento continuo de moderada intensidad, durante 12 semanas y 2 días/semana, produce mayores mejoras en los biomarcadores sanguíneos y metabólicos, en la composición corporal y en la condición física de los adultos con HTA, que las producidas por el entrenamiento continuo de moderada intensidad y el entrenamiento de fuerza combinado con entrenamiento interválico de alta intensidad, que también presentan mejoras, pero en menor medida. Y, por último, el estudio 4 muestra la importancia de una correcta y segura prescripción del entrenamiento combinado de manera individualizada para los adultos con HTA.

PALABRAS CLAVE

Presión arterial, hipertensión, enfermedad cardiovascular, condición física, ejercicio, actividad física, relación carga-velocidad, entrenamiento basado en la velocidad, entrenamiento combinado, entrenamiento de fuerza; MICT; HIIT.

ABSTRACT

Recent epidemiological studies continue to rank cardiovascular disease as the leading cause of death worldwide. These studies also identify high blood pressure (HBP) as the main modifiable risk factor for cardiovascular death globally, accounting for more than 10 million deaths per year.

Hypertension is considered a chronic disorder with a multifactorial etiology in which blood pressure levels remain permanently elevated. A distinction can be made between primary and secondary hypertension, the most common being essential or primary hypertension, which accounts for approximately 90-95% of cases. This presents a series of risk factors of biological origin or non-modifiable and environmental or modifiable in nature, the latter associated with lifestyle. More than 50% of people with hypertension are overweight or obese, have hypercholesterolemia, dyslipidemia, insulin resistance, or type II diabetes, are sedentary, and/or have a poor diet. European guidelines on cardiology and hypertension consider hypertension to be present when systolic blood pressure (SBP) levels are equal to or greater than 140 mmHg and/or diastolic blood pressure (DBP) levels are equal to or greater than 90 mmHg. On the other hand, American guidelines establish hypertension levels above 130 mmHg for SBP and 80 mmHg for DBP.

Non-pharmacological therapeutic interventions, which involve changes in habits and behaviors, are becoming increasingly popular in the clinical setting. Among these interventions, one of the most important for improving cardiometabolic health is regular physical exercise maintained over time. There is sufficient scientific evidence to affirm that physical exercise acts as a drug capable of preventing and treating numerous noncommunicable diseases in today's society, including hypertension.

Clinical guidelines on cardiology and hypertension contain specific sections setting out physical exercise recommendations for this population group. Aerobic endurance training is the main modality, and it is recommended to do 150-300 min/week (5-7 days/week) if the intensity is moderate and to alternate it with 75-150 min/week (2-3 days/week) if the intensity is vigorous. These guidelines recommend implementing aerobic endurance training with strength training at least 2 days/week, without going into much more detail about their prescription.

Both types of training have shown significant reductions in blood pressure levels; however, these recommendations do not refer to combined training of both types in the same session. There are studies with combined training interventions in this population group, and the results have been positive, achieving significant reductions in blood pressure in adults with hypertension. Despite these results, further research is needed to establish dose-response relationships, due to the heterogeneity of the protocols used. In recent years, high-intensity interval training (HIIT) has gained popularity in the clinical setting. This type of exercise has shown great benefits for cardiometabolic health and specifically for blood pressure levels.

Training programming, and more specifically strength training programming, is a complex task. Commonly, in the literature on the subject, work intensity has been determined based on the value of a maximum repetition (1RM), considered the gold standard, or a maximum number of repetitions (xRM); both methods are inaccurate for correctly measuring effort and can even be harmful when the subject is a beginner or has little experience in physical exercise. To address these limitations, execution speed has been proposed as a tool through which the degree of effort in strength training can be programmed objectively and with the greatest possible precision.

Based on the above, the objectives of this doctoral thesis were:

1) To evaluate the impact of multicomponent training on blood pressure in adults with hypertension and establish a dose-response relationship.

2) To compare the effect of two different physical exercise programs (EG1, strength combined with moderate-intensity continuous training; EG2, moderate-intensity continuous training) and a control group on blood and metabolic biomarkers, body composition, and physical condition in adults with SBP.

3) Compare the effects of three different physical exercise programs (EG1, moderate-intensity continuous training; EG2, strength training combined with moderate-intensity continuous training; EG3, strength training combined with HIIT) and a control group on blood and metabolic biomarkers, body composition, and physical fitness in adults with hypertension.

4) Provide healthcare professionals, cardiologists, sports cardiologists, primary care physicians, and CAFyD (Graduates in Physical Activity and Sports

Sciences) with recommendations on how to accurately, appropriately, and safely prescribe an exercise program for adults with hypertension.

Regarding the issues raised in the objectives, four studies have been carried out in this doctoral thesis:

1) Multicomponent training and optimal dosing strategies for adults with hypertension: systematic review and meta-analysis of randomized controlled trials.

2) Concurrent training based on an individual assessment of the load-speed relationship as a better alternative to continuous endurance training for improving hypertension.

3) Continuous moderate-intensity training, continuous combined moderate-intensity training versus combined high-intensity interval training in adults with hypertension: randomized controlled trial.

4) Design of an individualized combined training program for adults with high blood pressure.

Study 1 conducted a systematic review and meta-analysis examining the effects of a multicomponent training intervention program on blood pressure levels in adults with hypertension. The PRISMA statement guidelines were followed, and the study was registered in PROSPERO. Nine studies were included, following a literature search in various databases, including PubMed, Web of Science, Cochrane, and EBSCO. Only randomized controlled trials that performed multicomponent training interventions in adults with hypertension were considered for inclusion. In addition, quality assessment was performed using the PEDro scale, and a random-effects model was used for all analyses.

Studies 2 and 3 presented two original papers resulting from the Heart and Health project. A randomized, single-blind, longitudinal, prospective clinical trial was conducted with several simultaneous study branches. The intervention period was 12 weeks with a training frequency of 2 days per week and a duration of 60 minutes per training session.

Study 2 involved 75 volunteers, 36 women and 39 men, with a mean age of 54 years, all of whom had diagnosed hypertension and were sedentary, having never exercised before or at least not during the previous 12 months. The sample was randomly divided into two intervention groups. The experimental group (EG)

1 performed a strength training program based on an assessment using the individual load-speed ratio combined with MICT (n=25). EG2 performed MICT (n=25). The control group (CG) continued their lifestyle without modifications (n=25).

For study 3, there were 100 volunteers, 51 women and 49 men, with an average age of 54, all of whom had diagnosed hypertension and were sedentary. The sample was randomly divided into three intervention groups. EG1 performed MICT (n=25); EG2 performed strength training based on an assessment of individual load-speed ratio, combined with MICT (n=24); EG3 performed strength training based on an assessment of individual load-speed ratio, combined with HIIT (n=23). The CG continued their lifestyle without modifications (n=25).

All participants were assessed at the beginning and end of the intervention for the following dependent variables: SBP, DBP, and mean arterial pressure (MAP), pulse pressure (PP), double product (DP), maximum heart rate (HRmax), baseline heart rate (baseline HR), weight, musculoskeletal mass, fat mass, visceral fat area, lipid profile, total cholesterol (TC), HDL, LDL, triglycerides (TG), glucose, maximum strength, and cardiorespiratory capacity.

Study 4 produced a document with recommendations and protocols for the individualized prescription of physical exercise in adults with hypertension. This document aims to provide guidance to healthcare professionals on how to correctly design a strength training program based on an assessment of the individual load-speed ratio, combined with moderate-intensity continuous training, with the aim of improving cardiometabolic health in this population and preventing future adverse cardiovascular events. The document provides guidelines for dosing the load or work stimulus for both training modalities as accurately and safely as possible.

In conclusion, study 1 indicates that multicomponent training programs significantly improved SBP and DBP levels in adults with hypertension. The greatest benefits were found in programs lasting longer than 14 weeks, with three 60-minute sessions per week and intensities of around 75% of reserve heart rate for aerobic endurance training and greater than 75% of 1 RM, with 10 or fewer repetitions per set, for strength training. Studies 2 and 3 reveal how to perform a strength training program, based on an assessment using the individual load-speed ratio, combined with moderate-intensity continuous training, for 12 weeks and 2

days/week produces greater improvements in blood and metabolic biomarkers, body composition, and physical condition in adults with hypertension than those produced by moderate-intensity continuous training and strength training combined with high-intensity interval training, which also show improvements, but to a lesser extent. Finally, study 4 shows the importance of correct and safe prescription of individualized combined training for adults with hypertension.

KEYWORDS

Blood pressure, hypertension, cardiovascular disease, physical condition, exercise, physical activity, load-speed ratio, speed-based training, combined training, strength training; MICT; HIIT.

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Llegados a este punto, tan cerca de conseguir uno de los reconocimientos más importantes de mi vida, como es el de alcanzar el grado de Doctora en Ciencias del Deporte, creo que es conveniente y casi obligatorio echar la vista atrás para recordar el duro camino y agradecer a las personas que me han acompañado hasta el final. Todo comenzó en el año 2020, durante el confinamiento de la pandemia, cuando me inscribí en un Experto Universitario de Prescripción de Ejercicio Físico y Patología Cardiovascular. Todo un descubrimiento para mí; me apasionaba, había encontrado algo en lo que podía invertir horas y parecían minutos, había encontrado un hueco en el que podía encajar y aportar mi granito de arena. Fue uno de esos días, inmersa en ese apasionante mundo de la cardiología, cuando llamé a una gran amiga y le dije: "¡Me he decidido!, ¡Voy hacer el doctorado! Creo que he encontrado mi sitio y un tema que me motiva y merece la pena". Aquí comenzaba una larga y dura etapa de cinco años, repleta de obstáculos, pero que rodeada de las personas adecuadas he conseguido culminar con éxito. Antes de comenzar, me gustaría disculparme por si no logro elegir las palabras adecuadas para expresar mi inmensa gratitud a cada una de las personas aquí mencionadas. Sin más, quiero dar las gracias a:

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"Nunca dudes que un pequeño grupo de personas comprometidas puede cambiar el mundo. De hecho, sólo eso puede cambiarlo". Margaret Mead (1901-1978).

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SIGLAS Y ABREVIATURAS

Ang, Angiotensina

AT1R, Receptor Tipo 1 de Angiotensina

AT2R, Receptor Tipo 2 de Angiotensina

AT, Aerobic Training

BMI, Body Mass Index

BP, Blood Pressure

BFP, Body Fat Percentage

CT, Colesterol Total

CAFyD, Ciencias de la Actividad Física y el Deporte

CG, Control Group

CI, Confidence Interval

DP, Doble Producto

DBP, Diastolic Blood Pressure

ESC, Sociedad Europea de Cardiología

ECA, Encima Convertidora de Angiotensina

EDHF, Factor Hiperpolarizante Derivado del Endotelio

ET, Endotelina

EST, Eccentric Strength Training

EG, Experimental Group

EST, Eccentric Strength Training

FC, Frecuencia Cardiaca

GE, Grupo Experimental

GC, Grupo Control

HTA, Hipertensión Arterial

HTN, Arterial Hypertension

HIIT, Entrenamiento Interválico de Alta Intensidad

HDL, High Density Lipoprotein

HR, Heart Rate

HRV, Heart Rate Variability

HRR, Heart Rate Reserve

HRmax, maximum Heart Rate

INE, Instituto Nacional de Estadística

LDL, Low Density Lipoprotein

LBM, Lean Body Mass

LA, left arm

LL, Lower Limb

MAP, Mean Blood Pressure

mmHg, milímetros de mercurio

MICT, Entrenamiento Continuo de Moderada Intensidad

MCT, Multicomponent Training

MCP, Proteína Quimioatrayente de Monocitos

ME, Mobility Exercise

MD, Mean Difference

MPV, mean propulsive velocity

NO, Óxido Nítrico

n, Muestra

OMS, Organización Mundial de la Salud

PAS, Presión Arterial Sistólica

PAD, Presión Arterial Diastólica

PAM, Presión Arterial Media

PP, Presión de Pulso

PRISMA, Systematic reviews and Meta-Analyses

PG, Prostaglandina

PDGF, Factor de Crecimiento Derivado de Plaquetas

p, significance

RM, Repetición Máxima

ROS, Especies Reactivas de Oxígeno

RPE, Rate of Perceived Exertion

RPP, Rate Pressure Product

RHR, Resting Heart Rate

RA, right arm

SNS, Sistema Nerviosa Simpático

SRAA, Sistema Renina Angiotensina Aldosterona

ST, Strength Training

SBP, Systolic Blood Pressure

S, Stretching

SS, Static Stretching

TG, triglicéridos

TXA, Tromboxano

TST, Traditional Strength Training

UL, Upper Limb

VF, Visceral Fat

VO2p, Peak oxygen consumption

WHO, World Healht Organization

xRM, número de Repeticiones Máximas

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ÍNDICE DE FIGURAS

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I – INTRODUCCIÓN

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La enfermedad cardiovascular forma parte del grupo de enfermedades no transmisibles más prevalentes de la sociedad actual y representan aproximadamente un tercio del total de las muertes en el mundo (Magnussen et al., 2023; Mensah et al., 2023). Entre los factores de riesgo modificables responsables de muerte cardiovascular a nivel mundial se encuentra la hipertensión arterial (HTA), con más de 10 millones por año (Fuchs & Whelton, 2020; Vaduganathan et al., 2022). El primer informe publicado por la OMS en 2023 sobre HTA, describe el devastador impacto global de esta enfermedad y destaca que sigue siendo un importante problema de salud pública; es un trastorno que contribuye en la aparición y desarrollo de la enfermedad cardiovascular (cardiopatía isquémica, accidente cerebrovascular, enfermedad arterial periférica o insuficiencia cardíaca), enfermedad renal crónica, lesión de órgano diana y muerte súbita (Fuchs & Whelton, 2020). Según dicho informe, la HTA afecta a una de cada tres personas en el mundo, cuatro de cada cinco afectadas no reciben el tratamiento adecuado y solamente una de cada cinco personas que la padecen tienen controlada la enfermedad (Kario et al., 2024; WHO, 2023). La incidencia de la HTA se ha duplicado en los últimos 30 años, pasando de 650 millones a 1300 millones de personas, y casi la mitad de ellas desconocen actualmente que sufren esta afección (Kario et al., 2024; WHO, 2023). La OMS, a través de este informe, advierte a los principales líderes mundiales para que en sus países amplíen las medidas de prevención necesarias e intentar así controlar la HTA hasta en un 50% de los casos. Este control sobre la enfermedad podría evitar 76 millones de muertes por enfermedad cardiovascular, 120 millones de accidentes cerebrovasculares, 79 millones de infartos agudos de miocardio y 17 millones de casos de insuficiencia cardiaca entre 2023 y 2050 (Kario et al., 2024; WHO, 2023).

Son necesarios nuevos planes y también nuevas estrategias para poder reducir la carga de mortalidad cardiovascular en el mundo. La Sociedad Europea de Cardiología (ESC) ha publicado recientemente una guía clínica actualizada, de las ya publicadas anteriormente y del análisis de la evidencia científica disponible sobre el tratamiento de la HTA, con la intención de proporcionar una base científica para el abordaje, manejo y prevención de la enfermedad (McEvoy et al., 2024). Este

documento de 2024 sigue definiendo la HTA, en consulta, como una PAS de ≥140 mmHg o una PAD de ≥90 mmHg. Sin embargo, entre las actualizaciones aparece una nueva categoría para la presión arterial denominada presión arterial elevada, que se define, en consulta, como una PAS de 120 a 139 mmHg o una PAD de 70 a 89 mmHg. Surge así una nueva clasificación de la presión arterial que se divide en tres categorías para todos los adultos: presión arterial no elevada, presión arterial elevada e hipertensión (McEvoy et al., 2024). El 90% de las personas con HTA sufren hipertensión esencial o primaria, donde la causa sigue siendo desconocida, mientras que solo un 10% sufren hipertensión secundaria, en la que la causa si es identificable (Gorostidi et al., 2022; Harrison et al., 2021).

Los factores conductuales forman parte de la compleja fisiopatología de la HTA (Dempsey et al., 2018; Pantell et al., 2019). Entre esos factores, un comportamiento sedentario, la falta de actividad física y ejercicio, es un importante promotor de la enfermedad en la población adulta general, con graves consecuencias para la mortalidad por todas las causas y por enfermedad cardiovascular (Dempsey et al., 2018; Perry et al., 2023). Las recomendaciones actuales de las principales guías de cardiología e hipertensión sobre ejercicio físico en este grupo de población se centran en el entrenamiento de resistencia aeróbica, se propone como la terapia de ejercicio de primera línea frente a otras modalidades como puede ser el entrenamiento de fuerza. Se aconseja realizar al menos de 150 a 300 min/semana de ejercicio continuo de moderada intensidad (MICT), la frecuencia 5-7 días/semana; alternativamente se puede realizar de 75 a 150 min/semana de intensidad vigorosa, la frecuencia de 3 días/semana (Charchar et al., 2024; Hansen et al., 2021; Mancia et al., 2023; McEvoy et al., 2024; Pelliccia et al., 2020; Rabi et al., 2020; Unger et al., 2020; Whelton et al., 2018a). Además, esta modalidad debe ser complementada con el entrenamiento de fuerza, la frecuencia 2-3 días/semana, y realizar 2-3 series de 10-15 repeticiones por ejercicio a una intensidad del 40% al 80% de 1RM (Alves et al., 2022; Hansen et al., 2021; McEvoy et al., 2024; Whelton et al., 2018a). En estas guías no se exponen recomendaciones sobre entrenamiento combinado, resistencia aeróbica y fuerza, en la misma sesión. Sin embargo, la evidencia disponible de trabajos originales ha mostrado los beneficios de este tipo de intervención sobre los niveles de presión arterial consiguiendo reducciones significativas de PAS y PAD (Dos Santos et al., 2014; Lima et al., 2017; López-Ruiz et al., 2023; López-Ruiz et al., 2025; Masroor et al.,

2018; Stewart et al., 2005). Otra modalidad de entrenamiento que también ha mostrado mejoras sobre los niveles de presión arterial es el entrenamiento interválico de alta intensidad (HIIT), con reducciones de PAS y PAD similares o incluso mayores a las obtenidas con el MICT (Costa et al., 2018; Li et al., 2022; López-Ruiz et al., 2025; Way et al., 2019). El HIIT está irrumpiendo con fuerza e incluso se posiciona como alternativa al MICT por varias razones, por un lado, su creciente evidencia sobre los beneficios de esta modalidad de entrenamiento para la salud cardiometabólica y por otro lado, por la eficiencia del tiempo (Costa et al., 2018; Li et al., 2022; Way et al., 2019).

Está ampliamente demostrado que la práctica de ejercicio físico de forma regular disminuye el riesgo de sufrir HTA y que una vez se manifiesta la enfermedad es una terapia muy efectiva para su control y tratamiento (Ghadieh & Saab, 2015; López-Ruiz et al., 2023; Saco-Ledo et al., 2022). La prescripción de ejercicio individualizado es la manera más adecuada de conseguir los mayores beneficios para la salud cardiometabólica y al mismo tiempo la mejora de la condición física de las personas (López-Ruiz et al., 2025; San-Millán, 2023). Dentro del proceso de prescripción, la programación del entrenamiento es una tarea complicada para los profesionales del ejercicio, y esta complicación aumenta cuando se trata de programar el grado de esfuerzo en el entrenamiento de fuerza. En todos los estudios realizados hasta la fecha sobre HTA y entrenamiento de fuerza se han utilizado métodos poco precisos e incluso lesivos para programar el estímulo o carga de trabajo, como el test de 1RM o el de xRM (Badillo & Serna, 2002; González-Badillo et al., 2022). Toda esta problemática se ve solventada cuando emerge la velocidad de ejecución, herramienta que supone un cambio de paradigma en el campo del entrenamiento de fuerza al ofrecer información precisa sobre la carga programada y los efectos producidos por la misma (Badillo, 2017; González-Badillo & Sánchez-Medina, 2010; Sánchez-Medina & González-Badillo, 2011).

Considerando todo lo expuesto y la evidencia disponible, la presente investigación se centra en el estudio del efecto de diferentes programas de ejercicio físico individualizado frente a un grupo control sobre los parámetros de hemodinámica, composición corporal, perfil lipídico y condición física de adultos con HTA. Los diferentes programas de ejercicio físico son: 1) entrenamiento continuo de moderada intensidad o MICT; 2) entrenamiento de fuerza, basado en

una valoración mediante la relación carga-velocidad individual, combinado con MICT; 3) entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con HIIT.

II – JUSTIFICACIÓN

II - JUSTIFICACIÓN

La HTA sigue siendo el principal factor de riesgo modificable de muertes cardiovasculares prematuras en el mundo, afecta a 1.300 millones de personas adultas y mata a más de 10 millones por año (Murray et al., 2020; Vaduganathan et al., 2022; WHO, 2023). Este trastorno está directamente relacionado con la enfermedad cardiovascular y particularmente con la cardiopatía isquémica y el accidente cerebrovascular (Fuchs & Whelton, 2020; Razo et al., 2022; Vaduganathan et al., 2022), ambas patologías ocupan los primeros puestos en el raking mundial de las principales causas de muerte en el mundo, la primera y segunda posición respectivamente. La cardiopatía isquémica o enfermedad coronaria es responsable de más de 9 millones de muertes al año y el accidente cerebrovascular de casi 4 millones, la mayoría de estas muertes tienen como detonante a la HTA (Razo et al., 2022; Vaduganathan et al., 2022). La HTA representa un importante agente causal para el desarrollo de la enfermedad coronaria y sus diferentes manifestaciones isquémicas agudas, entre otras enfermedades cardiovasculares (Fuchs & Whelton, 2020; Razo et al., 2022; Vaduganathan et al., 2022).

En Europa se estima que casi el 50% de la población sufre HTA y este porcentaje aumenta hasta el 60% en mayores de 60 años. Alrededor del 40% de todas las muertes que se producen en este continente son por enfermedad cardiovascular con la HTA como factor detonante (Hanssen et al., 2022).

España es uno de los países europeos que cuenta con una alta prevalencia de HTA, se sitúa por encima del 30% de la población, casi 10 millones de españoles sufren este trastorno, y de estos, tan solo el 3,5 están tratados y controlados (Banegas et al., 2024). El número de muertes por eventos cardiovasculares atribuibles a la HTA en España es de aproximadamente 46 mil/año (Banegas et al., 2024). Según datos actualizados del Instituto Nacional de Estadística en 2024, la enfermedad coronaria es la principal causa de muerte cardiovascular en el país, con más de 27 mil por año, seguida del accidente cerebrovascular, con más de 23 mil por año (INE, 2023).

Un diagnostico precoz y un manejo adecuado de la HTA es de suma importancia para hacer frente a la enfermedad y poder prevenir futuros eventos

adversos cardiovasculares, haciendo que las complicaciones de la HTA y el tratamiento para la misma sean un gran desafío socioeconómico y de atención médico-sanitaria a nivel mundial.

La OMS, en su primer informe sobre HTA publicado en 2023, informa del devastador impacto de esta enfermedad en el mundo y del gran problema de salud pública que supone. El organismo pide a todos los países que amplíen las coberturas para hacer frente a este asesino silencioso y así poder evitar 76 millones de muertes por enfermedad cardiovascular, 120 millones de accidentes cerebrovasculares, 79 millones de infartos agudos de miocardio y 17 millones de casos de insuficiencia cardiaca entre 2023 a 2050 (WHO, 2023).

2.1 Fisiopatología de la HTA y Enfermedad Cardiovascular

Los mecanismos fisiopatológicos de la HTA en la promoción y desarrollo de la enfermedad cardiovascular, y particularmente de la aterosclerosis, son complejos e involucran varios sistemas, entre ellos el Sistema Nervioso Simpático (SNS) y el Sistema Renina-Angiotensina-Aldosterona (SRAA) a través de múltiples mediadores locales y neurohormonales.

El SNS forma parte integral de los mecanismos de respuesta al estrés y del mantenimiento de la homeostasis cardiovascular del ser humano, juega un papel fundamental tanto en la regulación como en la función cardiovascular. La hiperactividad del SNS es crucial en el desarrollo de la HTA y de las complicaciones cardiovasculares a largo plazo por su estrecha relación con el SRAA (De Mello & Danser, 2000; Doughan et al., 2008; Patel et al., 2022). Con la activación simpática aumenta la producción y liberación de noradrenalina, la cual cumple sus funciones al unirse a sus receptores alfa1 (α_1) y beta1 (β_1) adrenérgicos. Por un lado, la unión de la noradrenalina a los β_1-receptores del miocardio aumenta la contractilidad y frecuencia cardiaca para aumentar el gasto cardiaco; y, por otro lado, la excitación simpática renal que induce, a través de la union de la noradrenalina a los β_1-receptores del aparato yuxtaglomerular, la secreción de renina y la reabsorción de sodio, esta última mediada por los α_1-receptores (Katsurada et al., 2021). La hiperactividad del SNS afecta al riñón, y tiene un efecto directo sobre el SRAA. Ambos sistemas forman parte de un círculo vicioso que aumenta progresivamente y en paralelo con la gravedad de la HTA.

El SRAA es un importante agente fisiopatológico implicado en la HTA, disfunción endotelial y enfermedad cardiovascular (Doughan et al., 2008; Watanabe et al., 2005). El SRAA juega un papel crucial en la regulación de la presión sanguínea y en la homeostasis del organismo en general. Este sistema se activa como consecuencia de una reducción de la perfusión renal o disminución de la presión arterial. En respuesta a estos estímulos, el aparato yuxtaglomerular secreta la enzima renina que convierte el angiotensinógeno (producido mayoritariamente en el hígado) en angiotensina I. Esta angiotensina I posteriormente, por la acción de la enzima convertidora de angiotensina (ECA) se convierte en angiotensina II (Ang II); un potente factor vasoconstrictor, tanto local como sistémico, y con acciones sobre el volumen extracelular de agua, modificando la reabsorción de agua y sodio a través de la aldosterona. Esta sustancia vasoactiva es clave en el desarrollo y complicaciones de numerosas patologías cardiovasculares, entre las que se encuentran la HTA, la aterosclerosis o la insuficiencia cardiaca, entre otras enfermedades (Carracedo & Ramírez, 2020). La Ang II ejerce sus funciones a través de la unión a sus receptores específicos de membrana, los AT_1R y AT_2R, teniendo mayor afinidad por los receptores AT_1R, situados, predominantemente, en el tejido vascular y en el miocardio. La Ang II participa activamente en la patogénesis de la enfermedad cardiovascular a distintos niveles, dado que es capaz de estimular la producción de especies reactivas de oxígeno en el espacio subendotelial, participa en la respuesta inflamatoria de la pared vascular, estimula la proliferación y la migración de células de músculo liso y favorece la ruptura de la placa de ateroma y la trombogenicidad de la misma; además, este potente factor vasoconstrictor induce hipertrofia y fibrosis del miocardio (De Mello & Danser, 2000; Watanabe et al., 2005). Por tanto, la Ang II juega un papel crucial en el origen y desarrollo de la enfermedad cardiovascular aterosclerótica (Gallo et al., 2022; Harrison et al., 2021).

La función endotelial juega un rol muy importante en la conservación de la salud cardiovascular y metabólica (Brandes, 2014; Gallo et al., 2022; Konukoglu & Uzun, 2017; Mancia et al., 2023). El endotelio es el órgano encargado de la integridad vascular y para ello cumple una serie de funciones autocrinas, paracrinas y endocrinas, entre las que se encuentran el de barrera selectiva, permeabilidad, regulación del tono vascular, hemostasia, coagulación, la inflamación, regulación inmunológica o la angiogénesis. En condiciones fisiológicas normales el endotelio tiene un fenotipo vasodilatador en el que

sintetiza, entre otras sustancias, óxido nítrico (NO), prostaglandina (PGI2), factor hiperpolarizante derivado del endotelio (EDHF) y existe una baja concentración de especies reactivas de oxígeno (ROS). Sin embargo, cuando el endotelio se daña se produce una disfunción endotelial, esto reduce o inhibe la producción de NO y estimula la secreción de sustancias vasoconstrictoras, proinflamatorias, protrombóticas y proaterogénicas. La endotelina-1 (ET-1) sería el factor vasoconstrictor más potente que junto a otras sustancias vasoactivas, la prostaglandina H2 (PGH2) el tromboxano A2 (TXA2), la proteína 1 quimioatrayente de monocitos (MCP-1) o el factor de crecimiento derivado de plaquetas (PDGF), favorecen una alta concentración de especies reactivas de oxígeno en el espacio subendotelial, un alto grado de inflamación vascular, la migración de monocitos al interior del vaso y la proliferación de las células del músculo liso de la capa media. Esto conduce a HTA y enfermedad cardiovascular aterosclerótica (Gallo et al., 2022; Konukoglu & Uzun, 2017; Mancia et al., 2023).

Existe una relación bidireccional entre la disfunción endotelial y la HTA. Por un lado, la disfunción endotelial puede preceder al desarrollo de la HTA, sus consecuencias serían una posible remodelación vascular y aumento de las resistencias periféricas. O, por otro lado, la disfunción endotelial puede suceder a la HTA, sus consecuencias serían una desregulación endotelial con inhibición de sustancias vasodilatadoras y secreción de sustancias vasoconstrictoras, lo que favorece un estado proinflamatorio y protrombótico para el desarrollo de placas de ateroma (Gallo et al., 2022; Konukoglu & Uzun, 2017).

2.2 Ejercicio Físico e HTA en el Adulto

La inactividad física representa una gran amenaza para la salud cardiovascular y metabólica de las personas. Según estudios epidemiológicos recientes a nivel mundial, se estima que una tercera parte de la población adulta (31.3%), unos 1.800 millones de personas, no cumple con los niveles recomendados de actividad física y ejercicio (Strain et al., 2024) y que esa ausencia de movimiento es responsable de 400.000 muertes cardiovasculares por año y de 832.000 muertes prematuras por todas las causas (Vaduganathan et al., 2022). Uno de los factores que más han contribuido y sigue contribuyendo al aumento de la incidencia de la HTA es la falta de actividad física o ejercicio. Estudios previos han demostrado la asociación inversa que existe entre la práctica de ejercicio físico y el desarrollo y progresión de la HTA, así como de la alta morbimortalidad por enfermedad

cardiovascular (Choi et al., 2024; Huai et al., 2013; Joseph et al., 2019; Liu et al., 2017). Por el contrario, una vida activa y la práctica de ejercicio físico se correlacionan con grandes beneficios para la salud cardiovascular, metabólica, neurológica o inmunológica. Existe suficiente evidencia científica para poder afirmar con rotundidad que el ejercicio físico en un potente fármaco capaz de prevenir y tratar numerosas enfermedades no transmisibles, entre ellas las más prevalentes a nivel mundial, la HTA, la cardiopatía isquémica (infarto agudo de miocardio) o el accidente cerebrovascular (ictus) (Brandt & Pedersen, 2010; Joseph et al., 2019; Pedersen & Saltin, 2015; San-Millan et al., 2024; San-Millán, 2023; Severinsen & Pedersen, 2020). La respuesta a por qué el ejercicio físico tiene grandes beneficios sobre la salud, y particularmente sobre la salud cardiovascular, se encuentra en el músculo y en la mitocondria, dos componentes fundamentales de los que depende en gran medida la salud de las personas. El músculo esquelético, junto con casi todos los principales órganos del cuerpo (corazón, cerebro, hígado, intestino o tejido adiposo), tiene la capacidad de secretar al torrente sanguíneo, mediante la contracción muscular, cientos de moléculas bioactivas conocidas como mioquinas o exerquinas (Pedersen & Saltin, 2015; Severinsen & Pedersen, 2020). Estas moléculas expresadas por los distintos órganos juegan un papel crucial tanto para la prevención como para el tratamiento de la HTA y la enfermedad cardiovascular y metabólica (Pedersen & Saltin, 2015; Severinsen & Pedersen, 2020). Otro de los puntos importantes que se deben abordar cuando se trata de preservar la salud cardiovascular es el de la salud celular. La disfunción mitocondrial, con la reducción del número de mitocondrias y las alteraciones en su bioenergética, está presente en las enfermedades o trastornos más prevalentes de la sociedad actual, aterosclerosis, dislipemia, resistencia a la insulina, diabetes tipo II, síndrome metabólico, enfermedades neurodegenerativas o el cáncer (San-Millan et al., 2024; San-Millán, 2021, 2023). De entre todas las estrategias conocidas hasta la fecha capaz de mejorar la problemática celular, se podría decir que la práctica de ejercicio físico es casi la única y más efectiva para mejorar la biogénesis mitocondrial y restablecer la bioenergética de estos orgánulos (Lim et al., 2022; San-Millan et al., 2024; San-Millán, 2021, 2023).

En el contexto del ejercicio físico para mejorar o tratar la HTA y la enfermedad cardiovascular, son las principales guías clínicas internacionales de cardiología e hipertensión las que marcan las directrices a seguir. Son pautas de

ejercicio muy generalizadas en las que solo se indican el tipo de ejercicio y la frecuencia e intensidad a la que se debe realizar, sin profundizar mucho más en el resto de componentes o variables del entrenamiento. Estas guías clínicas dan prioridad al entrenamiento de resistencia aeróbica y dejan en un segundo plano al entrenamiento de fuerza, como modalidad complementaria al entrenamiento de resistencia aeróbica. Las recomendaciones actuales de ejercicio físico para el entrenamiento de resistencia aeróbica son de 150 a 300 min/semana (≥30 min, 5-7 días/semana) si se realiza con una intensidad moderada y, alternativamente, de 75 a 150 min/semana (25 min, 3 días/semana) si se realiza con una intensidad vigorosa (Brook & Rajagopalan, 2018; Charchar et al., 2024; Gorostidi et al., 2022; McEvoy et al., 2024; Pelliccia et al., 2020; Rabi et al., 2020; Unger et al., 2020; Visseren et al., 2021). Los efectos de esta modalidad de entrenamiento sobre los niveles de presión arterial han sido estudiados y bien descritos en la literatura científica, mostrando reducciones en un rango de -4,9 a -12 mmHg para la PAS y de -3,4 a -5,8 mmHg para la PAD (Hanssen et al., 2022; Mancia et al., 2023). El ejercicio de resistencia aeróbica debe complementarse con el entrenamiento de fuerza 2-3 días/semana, realizar 2-3 series de 10 a 15 repeticiones y con una intensidad baja o moderada, entre el 40%-60% de 1RM. Algunas de estas guías también hacen referencia al entrenamiento de fuerza isométrica, recomiendan realizar 3 series de contracciones isométricas de 1 a 2 minutos en ejercicios de agarre manual, plancha o sentadilla contra la pared (Charchar et al., 2024; Hanssen et al., 2022; McEvoy et al., 2024). Esta modalidad de entrenamiento ha mostrado mejoras de entre -3,0 a -4,7 mmHg para la PAS y de -3,2 a -3,8 mmHg para la PAD (Hanssen et al., 2022; Mancia et al., 2023). Estos documentos clínicos no hacen recomendaciones de ejercicio combinado, resistencia aeróbica y fuerza, en la misma sesión de entrenamiento, a pesar de los resultados positivos de esta modalidad sobre los niveles de presión arterial. Diferentes ensayos controlados con intervenciones de entrenamiento combinado en la misma sesión han podido comprobar como existen reducciones significativas sobre los niveles de PAS y PAD con esta modalidad (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Sousa et al., 2013). En esta misma línea se pueden encontrar revisiones sistemáticas y metaanálisis cuyos resultados post intervención con entrenamiento combinado también mostraron reducciones significativas sobre los niveles de PAS y PAD (Corso et al., 2016; Herrod et al., 2018; López-Ruiz et al., 2023; Pescatello et

al., 2019). Sin embargo, a pesar de los beneficios obtenidos y demostrados con el entrenamiento combinado, existen grandes diferencias entre los protocolos de ejercicio físico aplicados en las diferentes investigaciones (frecuencia, intensidad, volumen, recuperación, selección de ejercicios y método), aunque lo más importante a destacar es que la cuantificación y control de la carga para el entrenamiento de fuerza se realizó con métodos poco precisos, la intensidad mediante el test de 1RM y el volumen con un número preestablecido de repeticiones, lo que hace muy difícil establecer una relación dosis-respuesta (Albalawi et al., 2017; López-Ruiz et al., 2023).

Por otra parte, el entrenamiento interválico de alta intensidad (HIIT), modalidad de entrenamiento con gran popularidad actualmente, también ha demostrado tener beneficios sobre la salud cardiovascular (Ramos et al., 2015). Recientemente, el HIIT se ha propuesto como una buena alternativa al MICT por dos motivos principalmente, uno, por su alta eficiencia de tiempo, y dos, por la creciente literatura que respalda su eficacia para reducir los niveles de presión arterial en personas con HTA (Costa et al., 2018; Li et al., 2022; Way et al., 2019). Tanto el HIIT como el MICT han mostrado tener efectos similares sobre las reducciones de la PAS y la PAD en población con HTA, no obstante, uno de los principales problemas que presenta esta modalidad de entrenamiento interválico es la falta de consenso internacional con respecto a los protocolos que se deben aplicar según el tipo de población (Ito, 2019; McGregor et al., 2023).

Diseñar correctamente un programa de entrenamiento es una tarea compleja para los CAFyD, entrenadores y demás profesionales del ejercicio, ya que implica la manipulación de una serie de variables del entrenamiento que interactúan entre sí y que podrán provocar las respuestas fisiológico para la mejora de la salud o la condición física con más o menos acierto (Badillo & Serna, 2002). Esta complejidad aumenta cuando se trata de programar el entrenamiento de la fuerza, y más aún, cuando se trata de prescripción de ejercicio en población con patología cardiovascular, entre otras patologías. De entre todos los componentes o variables del entrenamiento que se deben determinar y concretar para una adecuada y segura prescripción de ejercicio físico, la intensidad y el volumen son las dos más importantes para programar el grado de esfuerzo, es decir, para programar el estímulo o carga de trabajo (Badillo & Serna, 2002; Bird et al., 2005; Elvar & García-

Orea, 2019; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Torres-Torrelo, et al., 2020; Rodríguez-Rosell et al., 2018). La intensidad es definida como el grado de esfuerzo que exige la realización de un ejercicio en cada repetición (Badillo & Serna, 2002; Elvar & García-Orea, 2019). Cuando en la literatura se habla de la medición o valoración de la intensidad del entrenamiento de fuerza, se suele hacer en relación a determinados indicadores, los más comunes son el porcentaje de una repetición máxima (1RM), considerado el gold standard, o con respecto a un número máximo de repeticiones (xRM) (Badillo & Serna, 2002); este último porque existe un número medio de repeticiones máximas por serie que se puede realizar con cada % de 1RM (Badillo & Serna, 2002; Sánchez-Medina & González-Badillo, 2011). En base a la evidencia actual, ya no se considera necesario y tampoco aconsejable utilizar el % de la 1RM para programar el entrenamiento de fuerza, debido a que este indicador presenta una serie de limitaciones e inconvenientes como suponer un esfuerzo excesivo, conlleva un riesgo de lesión o es un método poco preciso para determinar la intensidad relativa (Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010). Pero la intensidad, por sí sola, no es suficiente para determinar y concretar adecuadamente el estímulo o carga de entrenamiento, esta debe ir asociada a otra variable del entrenamiento, concretamente con el volumen (Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2022). Tradicionalmente el volumen de entrenamiento se ha mal determinado estableciendo un número concreto de repeticiones a realizar dentro de cada serie ante una carga dada (Badillo & Serna, 2002; González-Badillo et al., 2022; González-Badillo et al., 2017; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina & González-Badillo, 2011). Por tanto, en todos los estudios, hasta la fecha, sobre entrenamiento de fuerza en población con HTA, los grupos de intervención que hayan programado la carga en base al % de 1RM o xRM y hayan establecido un mismo número de repeticiones por serie ante una carga dada, es muy probable que el grado de fatiga inducido por el entrenamiento haya sido muy distinto para cada uno de los participantes, debido a que la pérdida de fuerza y velocidad experimentada por cada sujeto en cada una de las series del entrenamiento puede haber sido muy diferente (Badillo & Serna, 2002; González-Badillo et al., 2022; González-Badillo et al., 2017; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina & González-Badillo, 2011).

Ante lo expuesto, se hace evidente la necesidad de encontrar una herramienta capaz de determinar y controlar adecuadamente la intensidad y el volumen y que permita conocer con suficiente precisión la dosificación de la carga de entrenamiento.

Poder medir la velocidad de ejecución significó un cambio de paradigma en lo referente al entrenamiento de la fuerza y una solución para la problemática descrita (Badillo, 2017; Badillo & Serna, 2002; González-Badillo et al., 2022). Poder utilizar la velocidad de ejecución como indicador de la intensidad relativa en el entrenamiento de fuerza supuso poder cuantificar y controlar objetivamente la carga de trabajo (Badillo, 2017; Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2022; Sánchez-Medina et al., 2017). Son muchos los estudios que ya han utilizado la velocidad de ejecución para programar el estímulo de entrenamiento en diferentes grupos de población, sujetos jóvenes y sanos (Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020), esclerosis múltiple (Andreu-Caravaca et al., 2020), cáncer (Díez-Fernández et al., 2023) o en adulto mayor (Marcos-Pardo et al., 2019). Sin embargo, no se conocen estudios previos en HTA que se haya cuantificado la intensidad y el volumen en el entrenamiento de fuerza a través de la velocidad de ejecución.

Por todo lo expuesto, es incuestionable la necesidad de nuevos estudios que permitan conocer la relación dosis-respuesta de ejercicio más efectiva para reducir los niveles de presión arterial en población con HTA. Sería una gran aportación al conocimiento del ámbito médico y Ciencias del Deporte conocer los efectos de un programa de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con entrenamiento continuo de moderada intensidad (MICT) o combinado con entrenamiento interválico de alta intensidad (HIIT).

III – OBJETIVOS

III - OBJETIVOS

3.1 OBJETIVOS GENERALES

1. Analizar la literatura científica sobre los efectos de las intervenciones con programas de entrenamiento multicomponente en la misma sesión sobre los niveles de presión arterial en adultos con HTA.
2. Conocer los efectos de diferentes programas de entrenamiento individualizado sobre los parámetros hemodinámicos, perfil lipídico, composición corporal y condición física en adultos con HTA.

3.2 OBJETIVOS ESPECÍFICOS

1. Evaluar los efectos del entrenamiento multicomponente sobre los niveles de PAS y PAD de adultos con hipertensión e identificar la dosis óptima de entrenamiento multicomponente para controlar la hipertensión en los adultos.
2. Comparar el efecto del entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con entrenamiento de resistencia frente al entrenamiento de resistencia sobre los biomarcadores sanguíneos y metabólicos, la composición corporal y la condición física en adultos con HTA.
3. Conocer los efectos de un programa de entrenamiento selectivo MICT frente al entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con MICT; y, frente al entrenamiento de fuerza, basado en la valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con HIIT sobre los niveles de PAS, PAD, PAM, PP, DP; colesterol total, HDL, LDL, triglicéridos y glucosa; fuerza máxima de hemisferio superior e inferior del cuerpo; y capacidad cardiorrespiratoria en adultos con HTA.
4. Proporcionar recomendaciones a los profesionales de la salud y del ejercicio (médicos y CAFyD) para poder cuantificar de forma adecuada, segura y lo más precisa posible el estímulo o carga de

trabajo en los programas de entrenamiento combinado para adultos con HTA.

IV – HIPÓTESIS

IV - HIPÓTESIS

4.1 HIPÓTESIS GENERALES

1. La literatura científica mostrará que el entrenamiento multicomponente en la misma sesión es efectivo para conseguir reducciones significativas de los niveles de presión arterial en adultos con HTA.
2. Un programa de entrenamiento combinado individualizado de fuerza y resistencia en la misma sesión, con una adecuada y precisa dosificación del esfuerzo, será la modalidad más efectiva frente a otros programas de entrenamiento para mejorar los niveles de presión arterial; perfil lipídico; niveles de glucosa en sangre; composición corporal y condición física en adultos con HTA.

4.2 HIPÓTESIS ESPECÍFICAS

1. El entrenamiento multicomponente será efectivo para reducir los niveles de PAS y PAD en adultos con HTA.
2. Un entrenamiento individualizado de fuerza, programado a través de la velocidad de ejecución, combinado en la misma sesión con MICT será más efectivo que un entrenamiento individualizado selectivo MICT para reducir los niveles de presión arterial en adultos con HTA.
3. Un entrenamiento individualizado de fuerza, programado a través de la velocidad de ejecución, combinado en la misma sesión con MICT será más efectivo que un entrenamiento individualizado de fuerza, programado a través de la velocidad de ejecución, combinado en la misma sesión con HIIT para reducir los niveles de presión arterial en adultos con HTA.
4. Se desarrollarán recomendaciones para un correcto diseño de programas de entrenamiento combinado individualizado en personas con HTA, incluyendo un programa combinado de fuerza y resistencia en la misma sesión que servirá de ayuda a los profesionales de la salud y del ejercicio (médicos y CAFyD) para la prescripción de

esta modalidad de entrenamiento en este grupo de población. Se describirán todos los componentes o variables del entrenamiento como la selección de ejercicios y distribución organizativa con la que se realizarán los mismos, la frecuencia, la intensidad, el volumen y el tiempo de recuperación entre series y ejercicios, además de contemplar otras consideraciones que se deben tener en cuenta para este grupo de población

V – MÉTODO, RESULTADOS Y DISCUSIÓN

V - MÉTODO, RESULTADOS Y DISCUSIÓN

El método, los resultados y la discusión de la presente tesis doctoral se componen de cuatro artículos científicos publicados en revistas sujetas a revisión por pares. A continuación, se describen las referencias de dichos artículos:

Artículo 1

López-Ruiz, I., Lozano, F., Masia, M. D., & González-Gálvez, N. (2023). Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Sports (Basel)*, *11*(6). https://doi.org/10.3390/sports11060115

JCR Impact Factor: 2.2; Quartile: Q2; Category: Sport Sciences (46/127).

SJR Impact Factor: 0.79; Quartile: Q1; Category: Physical Therapy, Sports Therapy and Rehabilitation (53/241).

Artículo 2

López-Ruiz, I., Ruiz-Poveda, F. L., Masía, M. D., Heredia-Elvar, J. R., & González Gálvez, N. (2025). Concurrent training based on an individual load-velocity ratio assessment as a better alternative to continuous endurance training to improve hypertension. Sci Rep 15, 35751 (2025). https://doi.org/10.1038/s41598-025-21195-z

JCR Impact Factor: 3.9; Quartile: Q1; Category: Multidisciplinary Sciences (25/135).

SJR Impact Factor: 0.87; Quartile: Q1; Category: Multidisciplinary (23/213).

Artículo 3

López-Ruiz, I., Ruiz-Poveda, F. L., Masía, M. D., Heredia-Elvar, J. R., & González Gálvez, N. (2025). Moderate intensity continuous training, combined moderate-intensity continuous training vs combined high-intensity interval training in adults with hypertension: Randomized controlled trial. *Complementary Therapies in Clinical Practice*, *59*, 101960. https://doi.org/https://doi.org/10.1016/j.ctcp.2025.101960

JCR Impact Factor: 2.2; Quartile: Q2; Category: Integrative & Complementary Medicine (17/43).

SJR Impact Factor: 0.71; Quartile: Q1; Category: Complementary and Alternative Medicine (13/108).

Artículo 4

López-Ruiz, I., Lozano, F., Masia, M. D., & González-Gálvez, D. D. N. (2025). Diseño de Programas de Entrenamiento Combinado Individualizado para Adultos con Hipertensión Arterial. *Cultura, Ciencia Y Deporte, (20)64.* https://doi.org/10.12800/ccd.v20i64.2368

JCR Impact Factor: 1.1; Quartile: Q3; Category: Hospitality, Leisure, Sport & Tourism (98/139).

SJR Impact Factor: 0.29; Quartile: Q1; Category: Cultural Studies (320/1398).

Va – ESTUDIO 1:

Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

Va - ESTUDIO 1: Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials.

5.1. ABSTRACT

Background: Non-pharmacological interventions have demonstrated efficacy in the prevention, management, and control of hypertension. Multicomponent training confers a host of benefits to the general populace. The aim of this research was to assess the impact of multicomponent training on the blood pressure of adults with hypertension and ascertain the nature of the dose–response relationship. (2) Methods: This systematic review adhered to the PRISMA guidelines and was registered in PROSPERO. Eight studies were included, following a literature search across PubMed, Web of Science, Cochrane, and EBSCO. Randomized controlled trials implementing multicomponent training interventions on adults with hypertension were considered for inclusion. A quality assessment was performed using the PEDro scale, with a random-effects model utilized for all analyses. (3) Results: Multicomponent training yielded a significant reduction in systolic (MD = −10.40, $p < 0.001$) and diastolic (MD = −5.97, $p < 0.001$) blood pressure relative to the control group. Interventions lasting over 14 weeks with a minimum frequency of three sessions per week, each lasting 60 min, were deemed most effective. (4) Conclusion: An optimal training intensity was achieved with 30 min of aerobic exercise at 75% of the heart rate reserve, whereas sets of 10 repetitions at 75% of one repetition maximum produced the best outcomes in strength training.

5.2. INTRODUCTION

Cardiovascular disease is the leading cause of premature death worldwide, and hypertension is one of its most prevalent risk factors (Roth et al., 2018; Stanaway et al., 2018). Approximately one-third of the world's adult population suffers from hypertension, a factor that increases the risks of heart disease, encephalopathy, and kidney disease, with hypertension topping the list of serious, non-communicable diseases responsible for 10.4 million deaths per year (Unger et

al., 2020). Non-pharmacological interventions have been shown to be effective in the prevention, management, and control of hypertension (Gómez et al., 2019). The World Health Organization recommend that all adults should undertake at least 150 min of moderate-intensity activity or at least 75 min of vigorous-intensity physical activity, or some equivalent combination of moderate-intensity and vigorous-intensity aerobic physical activity, per week. In addition, the guidelines recommend regular muscle-strengthening activity for all age groups (Bull et al., 2020). In this regard, the effect of cardiovascular training on blood pressure levels has been well established in the literature, with reductions ranging from −4.9 to −12 mmHg for systolic blood pressure (SBP) and from −3.4 to −5.8 mmHg for diastolic blood pressure (DBP) (Hanssen et al., 2022). Strength training has shown improvements in blood pressure ranging from −3.0 to −4.7 mmHg for SBP and from −3.2 to −3.8 mmHg for DBP (Hanssen et al., 2022).

A description of the combined effect of both cardiovascular and strength training has been attempted. Multicomponent training has been shown to be more effective than aerobic training for improving some variables (Rossi et al., 2016) and has been widely used and recommended in the older adult population to reduce frailty (Dent et al., 2019). In multicomponent training, work is performed with many types of exercise by combining the physical capacities of strength, cardiovascular endurance, flexibility, and balance in the same session (Marcos-Pardo et al., 2021). This training has shown positive effects on the health of the adults, with haemodynamic improvements and improvements in arterial stiffness observed (Li et al., 2015), as recommended by the American College of Sports Medicine and by the American Heart Association (Nelson et al., 2007).

Three similar systematic reviews have been conducted thus far. However, some aspects should be taken into consideration. The study by Corso et al. (2016) included subjects with and without cardiovascular pathologies, such as diabetes, as well as subjects with hypertension; it also included training in a single session (multicomponent training) and in several sessions (concurrent training). The statistical analysis with meta-analyses by Herrod et al. (2018) focused on the older adult population, and Pescatello et al. (2019) did not include meta-analyses.

On the other hand, many differences have been observed between the dosage of the training protocols applied (time, frequency, duration, intensity, or order of components) (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014;

Lima et al., 2017; Masroor et al., 2018; Schroeder et al., 2019; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005), and a good understanding of the optimal dosage of the multicomponent training according to the blood pressure levels of patients with hypertension would help optimise the prescription, control, and management of hypertension.

The present systematic review and meta-analysis hypothesises that (a) multicomponent training will be effective in reducing systolic and diastolic hypertension levels in subjects with hypertension, and (b) the multicomponent training protocol that will show the greatest benefits for blood pressure will apply moderate to vigorous intensities in cardiovascular work and moderate to high intensities in strength training. In addition, the present systematic review with a meta-analysis aims (a) to evaluate the effects of multicomponent training on SBP and DBP levels of adults with hypertension, and (b) to identify the optimal dosage of multicomponent training to manage hypertension in adults.

5.3. MATERIALS AND METHODS

5.3.1. **Study Desing**

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). In addition, this research followed the Cochrane Handbook for Systematic Reviews of Interventions (Higgins, 2011) and was registered in PROSPERO (number CRD42021247395).

5.3.2. **Eligibility Criteria**

The inclusion criteria for the articles were (a) a randomised controlled trial (RCT) design, (b) the study of adults (30–80 years old) with hypertension, (c) a multicomponent training intervention, (d) the inclusion of a control group that did not engage in any form of exercise, (e) 100% supervision, and (f) articles written in English, Spanish, or Portuguese.

The exclusion criteria were (a) multicomponent training that did not include physical exercise, (b) a sample composed of pregnant women and/or patients with

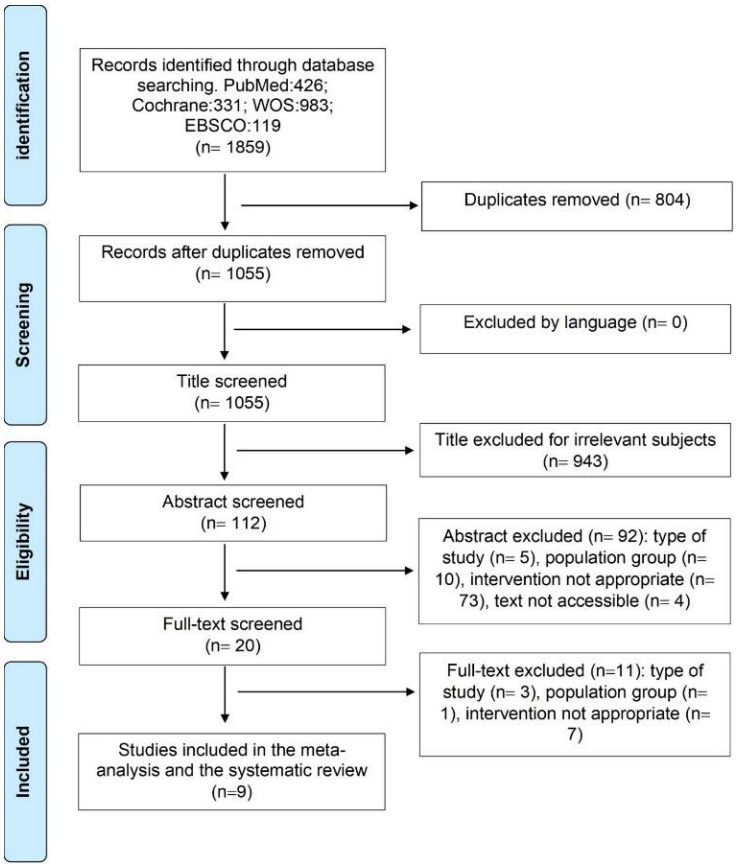
hypertensive and with severe diseases that precluded safe physical exercise (unstable coronary artery disease, heart or kidney failure, severe pulmonary hypertension, or uncontrolled diabetes), and (c) short communications, notes, letters, review articles, or brief reports.

5.3.3. **Search Strategy**

Four electronic databases (PubMed, Cochrane, WOS, and EBSCO) were used for the search, which ended in April 2022. No limitations for the starting year were defined in the search. The following search terms were used: hypertension, blood pressure, systolic, diastolic, and hypertensive, which were combined using the Boolean AND operator, with the following: exercise, training, sports, physical*, rehabilitat*, fit*, train*, strength*, aerobic*, endurance*, weight*, HIIT, MICT, fitness, resistance, combined, and multicomponent. The search strategy used in each database is detailed in Supplementary Table S1. A total of nine studies were included in the study (Figure 1).

Figure 1

Flow chart of studies searched, selected and included



5.3.4. **Data Collection and Synthesis**

Two reviewers (I.L.R. and N.G.G.) independently screened the literature in the selected databases using the search terms, considering the inclusion and exclusion criteria. In the case of any discrepancy regarding the inclusion of a given study, the data extraction or assessment were repeated without looking at the reviewer's previous information.

5.3.5. **Data Extraction and Study Quality**

A Physiotherapy Evidence Database (PEDro) score was used to assess the individual study of the quality. The score obtained showed a strong validity and inter-rater reliability for the assessment of RCTs (Morton, 2009; Egger et al., 1997; Rosenthal, 1979). A risk of bias summary graph was created to identify the authors' judgments, broken down according to each risk of bias criterion in all included studies.

Data extraction (table 1) and a quality assessment were performed by two reviewers (I.L.R. and N.G.G.) independently. Disagreements were resolved by repeating the data extraction or assessment without looking at the information previously reported by the reviewer. To determine the inter-reviewer reliability, Cohen's Kappa was calculated (McHugh, 2012) (Kappa = 0.899). To assess the risk of bias, Egger's publication bias test (Egger et al., 1997) and Rosenthal's failsafe-N (Rosenthal, 1979) were calculated, and funnel plots were created. The ability of Egger's test to detect bias when a meta-analysis is based on a small number of studies is limited (Sterne et al., 2011). In addition, the inclusion of at least 10 studies in the meta-analysis are necessary to perform it (Egger et al., 1997).

Table 1.

Data extraction for each included study

Studies	Sample	Age	Treatment	Inclusion criteria	Main variables
de Oliveira et al. (2019)	EG=13 CG=10	62.65±6.0 years	Diuretics, ARBs II, ACE inhibitors	≥50 years; controlled HTN; medical clearance for exercise, no physical activity in the last 6 months, no serious medical conditions	BP, Isometric Maximal Strength, Body Composition and VO2
Schroeder et al. (2019)	EG (MCT)=18, (AT), (ST) and (CG)=17	45-74 years 58±7	Untreated	SBP 120-149 and DBP 80-99 mm Hg without medication; BMI 25-40 kg/m2; sedentary; no serious medical conditions, non-smoker, non-pregnant	BP, HR, BMI, body composition, cardiorespiratory fitness and strength
Masroor et al. (2018)	EG=15 G=13	30-50 years 40.45±4.2	A drug (not specified)	sedentary women; premenopausal; stage 1 or 2 HTN, no serious medical conditions, no physical activity in the last 6 months	BP and HRV

Lima et al. (2017)	EG (MCT) and (AT)= 15, CG=14	60-75 years	Hydrochlorothiazid, ACE inhibitors and ARBs II	Antihypertensive medication, SBP < 160 mm Hg and DBP 105 mm Hg, non-smokers, no serious medical conditions, not obese II or III	BP, blood markers, cardiac hypertrophy, body composition, and VO2max
Son et al. (2016)	EG=10, CG=10	72-85 years 75±2	Untreated	Postmenopausal women; stage 1 HTN; non-obese; non-smokers; sedentary; non-medicated	BP, body composition, functional capacity, VO2max, arterial stiffness, endothelin-1 and nitrate
Guimaraes et al. (2014)	EG=16, CG=16	40-65 years 53.7±6.0	Diuretics, CCBs, ACE inhibitors, ARBs II, Beta-blockers	HBP >5 years, use of three antihypertensive drugs, no serious medical conditions, no physical activity in the last 6 months, non-smokers	BP and VO^2max

Dos Santos et al. (2014)	EG (TST)=20, (EST) and CG=20	60-65 years 63.1±2.3	CCBs, ACE inhibitors, ARBs II	Female, HTN, SBP < 180 and DBP < 110 mm Hg, sedentary, not diabetic, not on drugs and/or alcohol	BP and biochemical parameters
Sousa et al. (2013)	EG (MCT)=16 (AT)=15, CG=17	65-75 years (69.1±5.0)	A drug (not specified)	Older men, no diabetes, no severe obesity, no severe hypertension, no neurological, mental or cognitive impairment, no physical impairment.	BP, strength, lower limb aerobic endurance and body fatness
Stewart et al. (2005)	EG=51, CG=53	55-75 years 63.6±5.7	Untreated	Untreated mild hypertension, no physical activity in the last 6 months, non-smokers, no diabetes, no serious diseases.	BP, VO2max, Strength, Body Composition and Arterial Stiffness

Note. AT: Aerobic Training; ST: Strength Training; EST: Eccentric Strength Training; TST: Traditional Strength Training; MCT: Multicomponent Training; HR: Heart Rate; CG: Control Group; EG: Experimental Group.; HTN: Arterial Hypertension; BMI: Body Mass Index; BP: Blood Pressure; DBP: Diastolic Blood Pressure; SBP: Systolic Blood Pressure; HRV: Heart Rate Variability.

5.3.6. **Statistical Analysis**

R software, version 3.6.0., Copyright (C) 2019 (R Foundation for Statistical Computing, Vienna, Austria), was used with the metacont package to perform the meta-analysis. The forest plots were created using the forestplot package. For continuous data, the changes in the mean (M) and standard deviation (SD) between the baseline and final (pre–post-intervention) measurements of SBP and DBP values were used. Some studies had more than one experimental group and were treated as other subgroups in the analysis. We used the DerSimonian–Laird (Cohen's) clustering method and assessed heterogeneity using Cochrane's Q test (Chi^2), Higgins' I^2, and significance (p) to determine the appropriateness of applying a fixed or random effects model for the pooled analysis. If there was evidence of between-study heterogeneity ($I^2 > 50\%$, $p > 0.05$), random-effect estimates were described (Higgins et al., 2019).

To infer the pooled estimated standardised mean difference (MD), a meta-analysis with a random effects model was carried out (Higgins & Thompson, 2004). The DerSimonian–Laird (Cohen's) MD was interpreted by Cohen as small (0 to 0.2), medium (0.3 to 0.7), or large (≥0.8) (Cohen, 1988). Significant differences were determined at $p < 0.05$.

5.4. RESULTS

5.4.1. **Search Results and Study Characteristics**

The mean age of the sample was 60.7 ± 10.4 years, the mean duration of the intervention was 12 ± 8.3 weeks (range 4–32), and all interventions were supervised (table 2).

Table 2

Intervention programmes of the studies analysed.

Studies	Start	Training	Finish	T, F, D
de Oliveira et al. (2019)	10' running and S	Aerobic: 25' on treadmill, progressing the intensity by 5% every two weeks from 70% HRR to 80% HRR. Strength: 6 exercises (rowing, standing bench press, arm curl, knee extension, knee flexion, forward march with a resistance band) x 2 sets x 15 repetitions x 30'' between sets and exercises. Intensity measured with OMNI-Resistance exercise scale (RES); from 5 RPE progressing to 7 RPE and with the elastic bands, from low extensions to high tensions.	10' S and ME	8 wks, 3 days/wk, 70'
Schroeder et al. (2019)	-	Aerobic: 30' on treadmill or cycle ergometer at 40% HRR progressing to 70% HRR. Strength: 30' with 8 exercises (chest press, shoulder press, pull-down, lumbar extension, abdominal crunches, torso rotation, biceps curl, triceps extension, leg press, quadriceps extension, leg flexion and hip abduction) x 2	-	8 wks, 3days/wk, 60’

		sets of 18-20 reps max until progressing to 3 sets of 10-14 reps max, with 1-2' rest between sets.		
Masroor et al. (2018)	5' treadmill at 40% of HRmax	Aerobic: 20′ treadmill at 50%-80% HRmax (intensity increased gradually over 4 weeks) Strength: 5 exercises (bicep curls, triceps extensions, abdominal crunches, leg curls, and knee extensions) x 3 sets x 10 reps at an intensity of 50-80% of 1RM (intensity was gradually increased over 4 weeks).	5' treadmill at 40% of HRmax	4 wks, 5 days/wk, 50′-60′
Lima et al. (2017)	5'	Strength: 9 strength exercises (leg press, 45° leg press or bench press, bench extensor, front bench with handle, seated bench press, upright rowing, plantar flexion, seated rowing and crunches) x 15 repetitions (upper limbs) and 20 repetitions (lower limbs and trunk) with an intensity of 50%-60% 1 RM. From week 1 to 4 they performed 1 round and from week 5 to 10, 2 rounds. Aerobic: 20' on treadmill from week 1 to 4 and 30' from week 5 to 10. The intensity of the exercise was based on the physical condition of each participant.	-	10 wks, 3 days/wk, 40′-60′

Son et al. (2016)	5' SS	Strength: 20' exercises with elastic bands; 10 exercises (seated row, bicep curl, shoulder flexion, elbow flexion, push-up; hip flexion, hip extension, calf raise, leg press, squats). Aerobic: 30' of walking at an exercise intensity of 40% to 50% HRR from week 1 to 4, and 60% to 70% HRR from week 9-12.	5' SS	12 wks, 3 days/wk 60′
Guimaraes et al. (2014)	5'	Strength: 20' calisthenics in water (upper and lower limbs). Aerobic: 30' walking in water between 11 and 13 on the Borg scale.	5' S	12 wks, 3 days/wk, 60′
Dos Santos et al. (2014)	TST	Strength: 7 exercises (bench press with barbell, leg press, trunk extension, leg extension, arm curl, dorsiflexion, and lateral raises). Week 1 to 5 at 70% 10RM, week 6 to 11 at 80% of 10RM, and week 12 to 16 at 90% of 10RM. 3 sets x 10 reps. Aerobic: 20' on a treadmill at 65-75% HRR.	-	16 wks, 3 days/wk, 50′-60′
	EST	Strength work 30% 1RM more than in EFT. Same resistance work.	-	

Sousa et al. (2013)	10' walking and S	2 days of training on land and 1 day in the water. Aerobic: 30' with a choice between walking, jogging or dancing, with moderate intensity; in addition, 10' of muscle resistance with 3 exercises (with own body weight, upper and lower body), 3 sets, 15-20 repetitions. The aquatic session: relay races, water volleyball and water polo. Strength: 6 exercises (bench press, leg press, lateral leg extension, leg extension, leg curl, military press, leg curl and arm curl) at 65%R 1RM x 3 sets x 10-12 reps (MC1); 75%RM. 24 x 3 sets x 8-10 reps (MC2); 70%RM x 3 sets x 8-10 reps (MC3); 65%RM x 3 sets x 10-12 reps (MC4).	5′ S	32 wks, 3 days/wk, 60′
Stewart et al. (2005)	S	Strength: 7 exercises (latissimus dorsi pull down, leg extension, leg curl, bench press, leg press, shoulder press, and seated mid-row) x 2 sets x 10-15 reps at 50% 1RM. Aerobic: 45' with a choice of treadmill, exercise bike or stair climber. Intensity between 60%-90% HRmax.	-	24 wks, 3 days/wk, >60′

Note. ': minutes; 1RM: 1 Repetition Maximum; D: duration/session; S: Stretching; SS: Static Stretching; EST: Eccentric Strength Training; TST: Traditional Strength Training; F: weekly frequency; HRmax: maximum Heart Rate; HRR: Heart Rate Reserve; MC: Microcycle; ME: Mobility Exercise; Reps: repetitions; WKS: weeks; T: intervention time; RPE: Rate of Perceived Exertion

5.4.2. **Risk of Bias**

Table 3 shows the score obtained on the PEDro scale for each of the articles included. The results show that quality obtained between 8 and 10 points and was thus considered to be "high quality". Figure 2 shows the risk of bias summary: the authors' judgements are broken down according to each risk of bias criterion across all included studies.

Figure 2

Risk of bias summary: authors' judgements broken down according to each risk of bias criterion across all included studies.

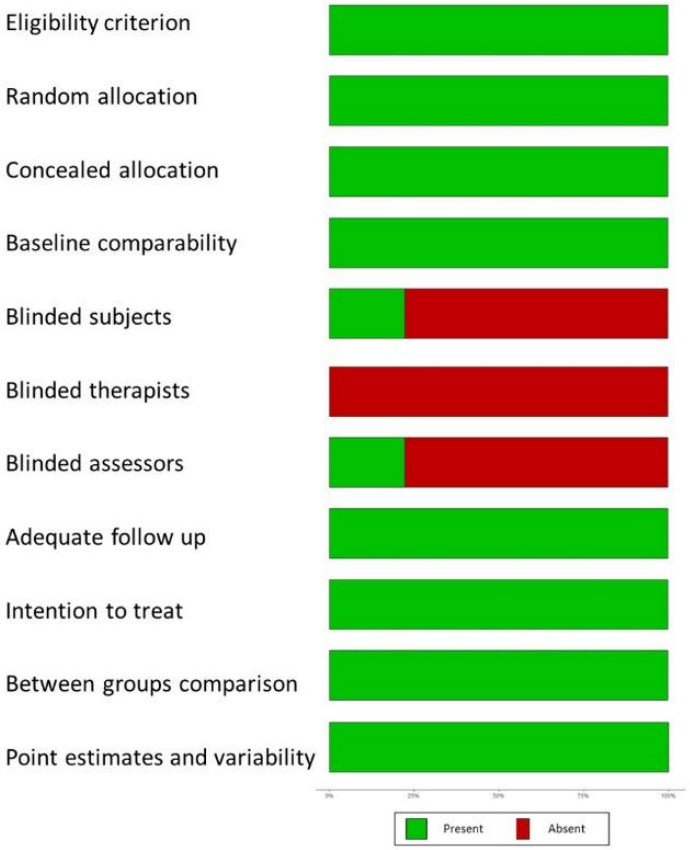


Table 3

Assessment of the methodological quality (PEDro scale) of the articles included.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	TOTAL
Oliveira et al. (2019)	1	1	1	1	1	0	0	1	1	1	1	9
Schroeder et al. (2019)	1	1	1	1	0	0	1	1	1	1	1	9
Masroor et al. (2018)	1	1	1	1	1	0	1	1	1	1	1	10
Lima et al. (2017)	1	1	1	1	0	0	0	1	1	1	1	8
Son et al. (2016)	1	1	1	1	0	0	0	1	1	1	1	8
Guimaraes et al. (2014)	1	1	1	1	0	0	0	1	1	1	1	8
Dos Santos et al. (2014)	1	1	1	1	0	0	0	1	1	1	1	8

Sousa et al. 2013)	1	1	1	1	0	0	0	1	1	1	1	8
Stewart et al. (2005)	1	1	1	1	0	0	0	1	1	1	1	8

Note. C1: choice criteria were specified; C2: subjects were randomly assigned to groups; C3: assignment was concealed; C4: groups were similar at baseline in relation to the most important prognostic indicators; C5: all subjects were blinded; C6: all therapists administering therapy were blinded; C7: all assessors measuring at least one key outcome were blinded; C8: measures of at least one of the key outcomes were obtained from more than 85% of the subjects initially assigned to the groups; C9: results were presented for all subjects who received treatment or were assigned to the control group, or, when this could not be done, data for at least one key outcome were analysed on an intention-to-treat basis; C10: results of statistical comparisons between groups were reported for at least one key outcome; C11: the study provides point-in-time and variability measures for at least one key outcome.

5.4.3. **Effect of the Interventions**

All the included studies showed significant improvements in SBP and DBP levels (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005) except for the study by Schroeder et al. (2019), which showed no improvements in peripheral and central systolic blood pressure levels; however, it did show improvements in peripheral and central diastolic blood pressure levels. Seven studies de Oliveira et al. (2019); dos Santos et al. (2014); Guimaraes et al. (2014); Lima et al. (2017); Masrror et al. (2018); Son et al. (2016); and Sousa et al. (2013) showed significant reductions ($p < 0.05$) in SBP and DBP levels in participants from the experimental group when compared to the control group; two of the studies Schroedes et al. (2019) and Stewart et al. (2005) did not show much improvement when compared to the control group.

The meta-analysis showed a significant reduction in SBP (MD = −10.40, 95% CI −17.49 to −3.32, $p < 0.001$) and DBP (MD= −5.97, 95% CI −9.20 to −2.74, $p < 0.001$) levels (Figure 3 and figure 4).

Figure 3

Forest plot comparing multicomponent training with supervision on changes in systolic blood pressure (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Schroeder et al., 2019; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005)

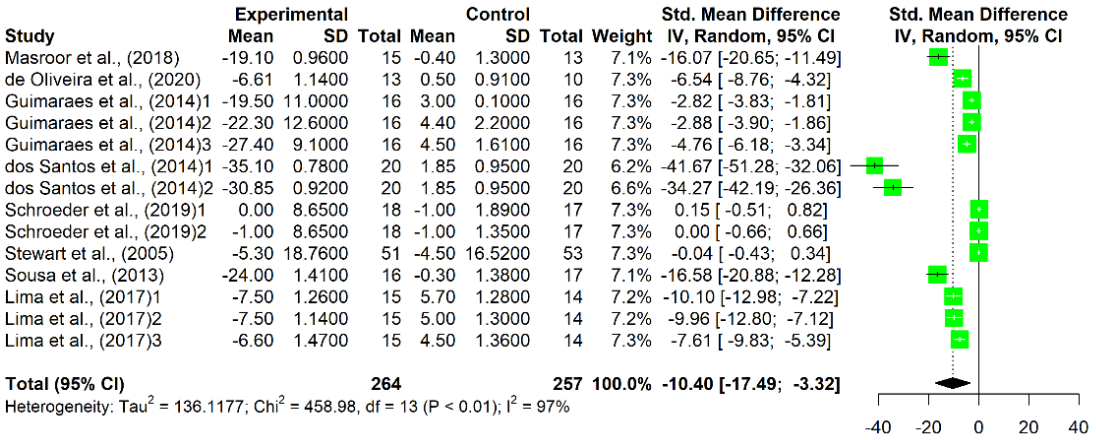
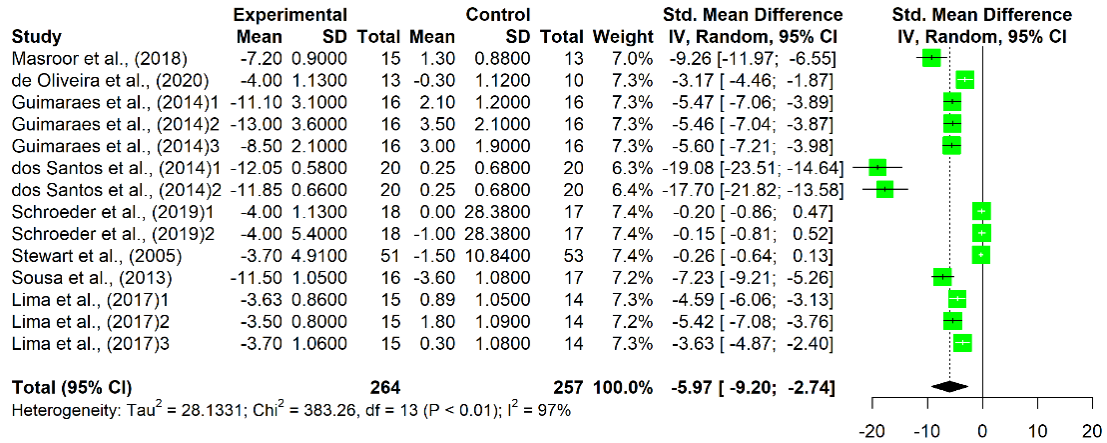


Figure 4

Forest plot comparing multicomponent training with supervision on changes in diastolic blood pressure (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Schroeder et al., 2019; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005)



The meta-analysis for SBP (Table 4) and DBP (Table 5) indicate that multicomponent training showed improvements independent of age and the weekly frequency and intensity of aerobic training. All program durations showed significant improvements in DBP and SBP; however, those with a duration longer than 14 weeks produced significantly greater improvements (SBP: MD = 0.36, p = 0.043, DBP: MD = 0.40, p = 0.024).

Table 4

Analysis of the effect of multicomponent training on SBP in patients with hypertension according to duration in weeks, weekly frequency, type of physical exercise programme applied, intensity, volume, and order of components.

	Authors	G	MD	95% CI	P	MD	95% CI	P
Age								
<65 years	Masroor et al. (2018), de Oliveira et al. (2019), Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Schroeder et al. (2019)	6	-2.2	-3.63; -0.78	0.002	-0.17	-0.58; 0.23	0.400
≥65 years	Sousa et al. (2013), Lima et al. (2017)	2	-1.06	-1.93; 0.2	0.016			
Weeks								
<14 weeks	Masroor et al. (2018), de Oliveira et al. (2019), Guimaraes et al. (2014), Schroeder et al. (2019), Lima et al. (2017)(Lima et al., 2017)	5	-0.97	-1.74; 0.21	0.012	0.36	-0.01; 0.70	0.043
≥14 weeks	dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Sousa et al. (2013)	3	-3.51	-5.74; -1.27	0.002			
Frequency								
3 days/ weeks	de Oliveira et al. (2019), Guimaraes et al. (2014), dos Santos et al. (2014), Schroeder et al. (2019) , Sousa et al. (2013), Lima et al. (2017)	6	-1.47	-2.53; -0.40	0.006	0.42	0.97; -0.12	0.130

>3 days/ weeks	Masroor et al. (2018)	1	-2.63	-3.63; -1.64	<0.001			
Intensity Aerobic Training								
≤75% HRR	Masroor et al. (2018), Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Schroeder et al. (2019)	5	-1.51	-4.26; -0.77	0.004	-0.05	-0.47; 0.37	0.819
>75% HRR	de Oliveira et al. (2019), Sousa et al. (2013)	2	-1.15	-1.87; -0.43	0.001			
Duration Aerobic Training								
<30 minutes	de Oliveira et al. (2019), dos Santos et al.(2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Lima et al. (2017)	4	-2.58	-4.61; -0.55	0.012	0.46	0.16; 0.76	0.002
≥30 minutes	Masroor et al. (2018), Guimaraes et al. (2014), Schroeder et al. (2019), Stewart et al. (2005), Sousa et al. (2013)	5	-5.25	-8.14; 2.35;	<0.001			
Intensity Strength Training								
≤75% 1 RM	Schroeder et al. (2019), Sousa et al. (2013), Lima et al. (2017)	3	-0.69	-1.55; 0.16	0.112	0.56	0.12;1	0.013
>75% 1 RM	Masroor et al. (2018), dos Santos et al. (2014) _1_TRT	2	-4.03	-6.86; -1.21	0.005			

Repetitions Strength Training									
≤ 10		Masroor et al. (2018), dos Santos et al. (2014) _1 TRT	2	-4.03	-6.86; -1.21	0.005	-0.61	-1.03; -0.18	0.005
> 10		de Oliveira et al. (2019), Schroeder et al. (2019), Sousa et al. (2013), Lima et al. (2017)	4	-0.71	-1.33; -0.08	0.026			
Order Training Components									
Aerobic	+	Masroor et al. (2018), de Oliveira et al. (2019), Schroeder et al. (2019)	3	-1.10	-2.52; 0.33	0.131	0.22	-0.16; 0.59	0.256
Strength	+	Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Lima et al. (2017)	4	-2.65	-4.59; -0.71	0.007			

Note. MD: Mean Difference; HRR: Heart Rate Reserve; CI: Confidence Interval; p: significance; MR: Maximum Repetition

Table 5

Analysis of the effect of multicomponent training on DBP in patients with hypertension according to duration in weeks, weekly frequency, type of physical exercise programme applied, intensity, volume, and order of components.

	Authors	G	MD	95% CI	P	MD	95% CI	P
Age								
<65 years	Masroor et al. (2018), de Oliveira et al. (2019), Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT. dos Santos et al. (2014) _2_ERT, Schroeder et al. (2019)	6	-1.79	-2.67; -0.91	<0.001	-0.20	-0.60; 0.2	0.326
≥65 years	Sousa et al. (2013), Lima et al. (2017)	2	-0.97	-1.60; -0.34	0.002			
Weeks								
<14 weeks	Masroor et al. (2018), de Oliveira et al. (2019), Guimaraes et al. (2014), Schroeder et al. (2019), Lima et al. (2017)	5	-1.04	-1.55; 0.54	<0.001	0.40	0.75; 0.05	0.024
≥14 weeks	dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Sousa et al. (2013)	3	-2.51	-3.83; -1.18	<0.001			
Frequency								

3 days/ weeks	de Oliveira et al. (2019), Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, Schroeder et al. (2019), Sousa et al. (2013), Lima et al. (2017)	6	-1.46	-2.26; 0.66	<0.001	-0.08	0.47; -0.62	0.784
>3 days/ weeks	Masroor et al. (2018)	1	-1.17	-1.95; 0.39	0.003			
Intensity Aerobic training								
≤75% HRR	Masroor et al. (2018), de Oliveira et al. (2019), Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Schroeder et al. (2019)	6	1.79	-2.67; 0.91	<0.001	-0.06	-0.58; 0.47	0.832
>75% HRR	Sousa et al. (2013)	1	-1.3	-2.07; -0.53	<0.001			
Intensity Strength Training								
≤75% 1 RM	Schroeder et al. (2019), Sousa et al. (2013), Lima et al. (2017)	3	-1.3	-2.06; -0.55	<0.001	0.21	0.64; -0.23	0.346
>75% 1 RM	Masroor et al. (2018), dos Santos et al. (2014) _1_TRT	2	-2.35	-4.71; 0.01	0.050			
Duration Aerobic training								

<30 minutes	de Oliveira et al. (2019), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Lima et al. (2017)	4	-1.84	-3.28; -0.39	0.012	0.21	-0.09; 0.51;	0.173
≥30 minutes	Masroor et al. (2018), Guimaraes et al. (2014), Schroeder et al. (2019), Stewart et al. (2005), Sousa et al. (2013)	5	-3.05	-5.26; -0.85	0.006			
Repetitions Strength Training								
≤ 10	Masroor et al. (2018), dos Santos et al. (2014) _1_TRT	2	-2.35	-4.71; 0.01	0.050	-0.26	0.15; -0.68	0.216
> 10	de Oliveira et al. (2019), Schroeder et al. (2019), Sousa et al. (2013). Lima et al. (2017)	4	-1.10	-1.76; 0.44	0.001			
Order Training Components								
Aerobic + Strength	Masroor et al. (2018), de Oliveira et al. (2019), Schroeder et al. (2019)	3	-1.21	-2.07; -0.36	0.005	0.16	-0.21; 0.53	0.398
Strength + Aerobic	Guimaraes et al. (2014), dos Santos et al. (2014) _1_TRT, dos Santos et al. (2014) _2_ERT, Lima et al. (2017)	4	-1.95	-3.27; -0.64	0.003			

Note. MD: Mean Difference; HRR: Heart Rate Reserve; CI: Confidence Interval; p: significance; MR: Maximum Repetition

Similar results were observed for the duration of the training session in relation to SBP, with the most significant improvements observed for a duration of 30 min or longer. In relation to DBP, both protocols showed significant reductions, with no differences between them.

In the strength component, a work intensity of less than 75% of one repetition maximum (1 RM) (or equivalent) did not produce significant improvements in SBP though higher intensities did, with a significant difference observed between the two intensities used ($p = 0.013$). With respect to DBP, an intensity lower or higher than 75% of 1 RM produced significant improvements with a tendency towards significance, with no differences between the two. Any number of repetitions produced significant improvements in both SBP and DBP levels. However, a lower number of repetitions (≤10) resulted in significantly greater improvements in SBP than a higher number of repetitions (>10) ($p = 0.005$).

The programmes that used aerobic work first and strength work second did not show a significant improvement in SBP values; those that applied the components in reverse did show a significant reduction (MD = −2.65; $p = 0.007$); however, the difference between groups was not significant. For DBP, significant improvements with no differences between them were found for both cases.

5.5. DISCUSSION

The main objective of the present study was to determine the effects of multicomponent training programmes on the SBP and DBP levels of adults with hypertension. The results confirm the first hypothesis formulated: multicomponent training will be effective in reducing systolic and diastolic hypertension levels in subjects with hypertension. The results showed that a multicomponent training programme achieved significant reductions in SBP and DBP levels in adults with hypertension, with these changes being significantly different from a control group. Individually, the works by Masroor et al. (2018), dos Santos et al. (2014), de Oliveira et al. (2019), Guimaraes et al. (2014), Sousa et al. (2013), and Lima et al. (2017) showed significant reductions in both SBP and DBP values post intervention with multicomponent training programmes. The study by Dos Santos et al. (2014) showed the greatest effects on SBP and DBP levels, and the study by Schroeder et al. (2019) only showed improvements in peripheral and central SBP levels and not

in peripheral and central DBP levels. This difference may be because the latter study included only subjects with uncontrolled mild hypertension compared to the inclusion of subjects with monitored grades one and two hypertension in the other studies.

Our findings are in line with those from other systematic reviews and meta-analyses (Cornelissen & Smart, 2013; Corso et al., 2016; Herrod et al., 2018; Pescatello et al., 2019). The works by Corso et al. (2016), Herrod et al. (2018), and Pescatello et al. (2019) described significant reductions in SBP and DBP levels with multicomponent training. It should be noted that in the study by Herrod et al. (2018), the intervention did not provide benefits that were any greater than single-mode training. In the review by Cornelissen et al. (2013), only significant reductions in DBP levels were obtained with multicomponent training, without changes observed in SBP values. On the other hand, one of the most recent reviews, written by Saco-Ledo et al. (2020), did not describe significant benefits on ambulatory blood pressure levels, specifying that significant benefits were only obtained with aerobic training programmes. However, the authors only included three studies in their systematic review that used multicomponent training, and one of them worked with people with mild hypertension, so the result may not be significant. The authors themselves indicated that more studies were needed for considering their results.

In this sense, multicomponent training as a physical activity programme is effective in playing an important role not only in primary but also in secondary cardiovascular prevention. In this regard, the effects of physical activity programmes on the metabolic environment and systemic chronic inflammation, as well as adaptations at the vascular and cardiac tissue levels, have been described (Bullard et al., 2019; Valenzuela et al., 2023). As in the studies previously mentioned, those included in the present systematic review and meta-analysis were highly heterogeneous in terms of the design of the multicomponent training programmes, suggesting that this may have an influence on the outcome of the SBP and DBP responses (Spiering et al., 2008; Taipale & Häkkinen, 2013), which will be discussed below.

These reductions in SBP and DBP can also be affected by drug treatment. In addition to commencing drug treatment, the patient with hypertension should

make lifestyle changes, such as including regular physical exercise (Pescatello et al., 2004; Williams et al., 2018). The studies by Sousa et al. (2013), dos Santos et al. (2014), Guimaraes et al. (2014), Lima et al. (2017), Masroor et al. (2018), and de Oliveira et al. (2019) included adults with monitored hypertension as the inclusion criteria. The participants in both the experimental and control groups had some pharmacological treatment that they continued to maintain during the study. After the completion of the multicomponent training interventions, the studies showed significant reductions in SBP and DBP levels, and these reductions differed from changes in the control group, who did not take part in the training programmes. However, the participants in the studies by Stewart et al. (2005) and Schroeder et al. (2019) had mild hypertension without pharmacological treatment as an inclusion criterion. The first (Stewart et al., 2005) showed significant reductions in SBP and DBP; however, these did not differ from changes in the control group, and the second (Schroeder et al., 2019) showed a reduction in SBP, which was significantly different compared to the control group but not in DBP. This could be due to the fact that multicomponent training may be more effective for higher levels of hypertension, and the differential results could also be due to the differences in the programmes implemented, as will be discussed below.

The second objective of the present study was to identify the optimal dosage of multicomponent training for managing hypertension in adults. The results confirm the second hypothesis: the multicomponent training protocol that will show the greatest benefits for blood pressure will be one that applies moderate to vigorous intensities in cardiovascular work and moderate to high intensities in strength training. Age is one of the risk factors that influences blood pressure levels, with the risk of hypertension increasing from the ages of 60–65 years old (Anandita et al., 2020). The present meta-analysis shows that multicomponent training produced significant improvements in SBP and DBP regardless of age when comparing studies that included a sample younger than 65 years old (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Masroor et al., 2018; Schroeder et al., 2019) with studies that included a sample older than 65 (Lima et al., 2017; Sousa et al., 2013). These positive results are due to the fact that regular physical exercise can prevent or reverse pathologies associated with aging, as is the case with hypertension and as reflected in studies such as the one by Marcos-Pardo et al. (2021) in its multi-domain intervention programme Healthy-Age.

Regarding the duration of the interventions, the results of the meta-analysis showed significant reductions in SBP and DBP levels with multicomponent training regardless of the duration of the programme. Of note, interventions lasting longer or equal to 14 weeks resulted in greater reductions in blood pressure levels. Acute adaptations to exercise occur from the start, with reductions of 10–20 mmHg in SBP after the end of the training session, with these effects lasting up to 22 h. If exercise is maintained regularly over time, these adaptations will become increasingly larger and chronic, with reductions of up to 10 mmHg in SBP and 8 mmHg in DBP (Pedersen & Saltin, 2015). Training programmes aimed at improving and managing hypertension should be considered as lifelong strategies to maintain these adaptations.

Regarding the frequency of the multicomponent training programmes, no significant differences were observed. The result of the meta-analysis indicated that reductions in SBP and DBP improved independently of the number of training days, with three days/week being the minimum frequency applied in the included studies. The exercise recommendations for hypertension from the American College of Sports Medicine and the latest hypertension clinical guidelines indicate the same frequency as the results obtained in this meta-analysis, with 3 days/week being the minimum training frequency recommended (Unger et al., 2020; Zaleski, 2019).

In relation to aerobic training, all the groups obtained significant reductions in SBP and DBP irrespective of work volume or intensity. However, the protocols that applied ≥30 min of work were shown to be more effective in reducing SBP. Regarding the minimum aerobic exercise time for improving hypertension, the main cardiology clinical guidelines state a minimum of 30 min per day, a length of time associated with reductions of 7 mm Hg for SBP and 5 mm Hg for DBP, with these guidelines in line with the results obtained in this meta-analysis.

In the protocols utilized for strength work, the studies that used a lower number of repetitions also showed a higher percentage of repetition maximum. The meta-analysis revealed that although both groups showed improvements, performing less than or equal to 10 repetitions produced greater reductions in SBP. In relation to the percentage of 1 RM, only work higher than 75% of 1 RM produced improvements in this variable. The DBP response was not different between

protocols that applied intensities lower than 75% of 1 RM than higher ones, nor between protocols that performed more than 10 repetitions versus those that performed fewer repetitions. In this sense, it follows that a higher-volume and lower-intensity strength work protocol could have a greater influence on blood pressure in subjects with hypertension. Training programmes aimed at improving strength at low–moderate work intensities provide many benefits for the adult population, with this being an effective stimulus for improving blood pressure levels (Zhang et al., 2021). The exercise recommendations for subjects with hypertension refer to the practice of 150–300 min of aerobic exercise per week at a moderate–vigorous intensity, including 2–3 days of strength exercise per week, without specifying intensities, series, or repetitions, making it difficult to compare the findings from this meta-analysis (Unger et al., 2020).

The present meta-analysis did not show significant differences with respect to the order of the exercise components, although the changes in the order were only significant for the group that first performed strength exercises and then aerobics (Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017). Some studies, such as those by Eklund et al. (2016), Schumann et al. (2014), or Wilhelm et al. (2014), can explain these results. In their work, with different types of populations, sedentary women, sedentary older adults, and active young men, it was observed that the order of the components in multicomponent training programmes did not affect the adaptations of each modality.

Strengths and limitations:

The main limitation of this systematic review and meta-analysis is the small number of RCTs that currently exist, the heterogeneity of the population included (sex and age), the heterogeneity of the protocols, the types of aerobic and strength training exercises, and the small sample sizes in some studies. These aspects limit the comparisons between the different intervention groups and indicate the need for new studies to provide new data that allows for the generalisation of results.

However, the studies analysed herein also had strengths, among which we must underline that they obtained scores between 8 and 10 on the PEDRO scale, a ranking considered “high quality” (Morton, 2009).

5.6. CONCLUSIONS

The results of this study indicate that multicomponent training programmes significantly improved the SBP and DBP levels of adults with hypertension. The greatest benefits were found in programmes lasting longer than 14 weeks with a frequency of at least three sessions per week and sessions lasting approximately 60 min. The intensity of aerobic training should be around 75% of the reserve HR, and the intensity of strength training should be greater than 75% of 1 RM, with 10 repetitions or less per set. This research provides relevant information for professionals who prescribe physical activity to subjects with hypertension, providing key guidelines for its implementation. In this regard, there are several future areas for research in this field. It is necessary to investigate if there are differences in the results of the application of two protocols with training that apply the different components in different sessions or in the same session. It is also considered relevant to investigate the influence of the type of activity during cardiovascular work.

Vb – ESTUDIO 2:

CONCURRENT TRAINING BASED ON AN INDIVIDUAL LOAD-VELOCITY RATIO ASSESSMENT AS A BETTER ALTERNATIVE TO CONTINUOUS ENDURANCE TRAINING TO IMPROVE HYPERTENSION

Vb - ESTUDIO 2: Concurrent training based on an individual load-velocity ratio assessment as a better alternative to continuous endurance training to improve hypertension

5.7. ABSTRACT

Hypertension remains a major global public health problem as the leading modifiable risk factor for cardiovascular death worldwide, responsible for more than 10 million deaths per year. The aim of the present study was to compare the effect of strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training, and endurance training on blood and metabolic biomarkers, body composition and physical fitness in adults with hypertension. A randomised, single-blind, 12-week, prospective clinical trial was conducted. The study included 75 volunteers with an average age of 54 years, all of whom were hypertensive and sedentary. The sample was randomly assigned into three groups, strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training, endurance training alone group, and a control group. The concurrent training group obtained greater reductions in SBP, DBP and MAP than the endurance training group, up to 12.8 mmHg, 6.8 mmHg and 8.6 mmHg respectively. The findings of the present study indicate that performing strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training 2 days per week for 12 weeks, leads to improvements in metabolic and blood biomarkers, body composition, and physical fitness, of adults with hypertension, with these adaptations being superior to those produced by endurance training alone.

Keywords: high blood pressure, exercise, combined training, strength training, velocity of execution, endurance.

5.8. INTRODUCTION

Presently, hypertension remains the main modifiable risk factor worldwide for premature cardiovascular deaths (Vaduganathan et al., 2022). Large epidemiological studies have shown an inverse relationship between the incidence of hypertension and exercise (Diaz & Shimbo, 2013; Liu et al., 2017), understood as

the set of ordered, structured and systematised movements aimed at improving health or physical condition. The most important clinical guidelines recommend exercise for subjects with hypertension, giving priority to endurance training (Pelliccia et al., 2020; Rabi et al., 2020; Whelton et al., 2018b). The effects of endurance training on hypertension have been studied and are well described in the literature, showing reductions in the range of -4.9 to -12 millimetres of mercury (mmHg) for systolic blood pressure (SBP) and -3.4 to -5.8 mmHg for diastolic blood pressure (DBP) (Hanssen et al., 2021; Mancia et al., 2023). Some guidelines recommend incorporating strength training as well (Whelton et al., 2018b), but few individuals comply with their prescription in depth (Hanssen et al., 2021). Strength training has shown improvements ranging from -3.0 to -4.7mmHg for SBP and -3.2 to -3.8mmHg for DBP (Hanssen et al., 2021; Mancia et al., 2023). In addition to these guidelines, the available evidence shows that concurrent training, understood as training that combines strength and endurance work in the same training session, has also shown great benefits on health, specifically on hypertension (Bavaresco Gambassi et al., 2024; Gambassi & Schwingel, 2024; López-Ruiz et al., 2023). Different controlled trials (Dos Santos et al., 2014; Masroor et al., 2018; Sousa et al., 2013) showed significant reductions in SBP and DBP levels with concurrent programme interventions (Costa Chaves et al., 2025; Herrod et al., 2018; López-Ruiz et al., 2023; Pescatello et al., 2019).

However, there are large differences among the protocols applied (frequency, intensity, volume, recovery time and characteristics, selection, organisation and distribution of exercises) in the different studies conducted (Diaz & Shimbo, 2013; López-Ruiz et al., 2023). Despite scientific evidence showing improvements in blood pressure levels and other metabolic markers with combined or concurrent training, further research is needed to gain a more specific understanding of the dose-response relationship of this type of training and to standardize such training programs (Amare et al., 2025; Hejazi et al., 2025; López-Ruiz et al., 2023). Recent studies indicate that due to the heterogeneity of research quality and heterogeneity in research protocols, further research is needed to determine the effect of these types of programs. This study is the first to apply a concurrent training program, considering the loss of running speed when prescribing repetitions (López-Ruiz et al., 2023; Poli et al., 2025). One of the main problems is the lack of precision in the quantification of the work stimulus in strength training, which makes it very

difficult to establish a dose-response relationship, as it is not known whether the intensity with which the participants trained was the same as that programmed and applied, as well as not knowing the degree of fatigue reached by each participant in each set or training session. A major difficulty in designing strength training programmes is how to accurately quantify and control the workload in order to obtain the greatest health and fitness benefits (González-Badillo et al., 2022). In order to address this problem, the focus has been on the velocity of execution (Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010). This form of effort programming has brought about a paradigm shift in the control of strength training (González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2022; Sánchez-Medina & González-Badillo, 2011). Despite all of the research on strength training through speed of execution and its positive results as a tool for training programming in the young population and athletes (Conceição et al., 2016; Sánchez-Medina & González-Badillo, 2011), cancer survivors (Díez-Fernández et al., 2023), multiple sclerosis and older adults (Andreu-Caravaca et al., 2020), there is still a gap in the health field in relation to the design of exercise programmes with this methodology, and especially in subjects with hypertension. Training methods such as velocity-based training should be prioritized over the repetitions until failure method to minimize the risk of overexertion (McClean et al., 2024; Motlagh & Lipps, 2024).

Therefore, the aim of the present study was to compare the effect of strength training, based on an individual load-velocity ratio assessment, combined with endurance training, and endurance training alone, on blood and metabolic biomarkers, body composition and physical fitness in adults with hypertension, by actually knowing the exercise dose applied in the training.

5.9. RESULTS

Table 1 shows the training monitoring results (HR, %HRmax, and RPE) for each group in each week. Participants showed a HR average of 113.74±11, a %HR max of 145.14±13.17, and an RPE of 3.16±0.92; there were no significant differences between the intervention groups. Tables 2 and 3 show the pre-post intervention results for EG1, EG2 and CG. The group * time interaction is also presented.

EG1 and EG2 showed significant improvements in SBP (mmHg), DBP (mmHg), mean arterial pressure (MAP) (mmHg), pulse pressure (PP) (mmHg), rate

pressure product (RPP), resting heart rate (RHR), lean mass (kg), body fat (%), waist circumference (cm), glucose (mg/dl), right handgrip (kg), left handgrip (kg), upper limb MPV (m/s 50%), %RM UB, lower limb MPV (m/s 60%), and VO_2peak (ml/kg/min). These changes were significantly different from the CG changes. Specifically, EG1 showed greater improvements of up to -12.8 mmHg in SBP, -6.8 mmHg in DBP and -8.6 in MAP over EG2. Improvements in PP, waist circumference, upper limb PWV (m/s 50%), 1RM (LB), lower limb PWV (m/s 60%) and VO_2peak (ml/kg/min) were also greater in EG1 than in EG2.

5.10. DISCUSSION

The aim of this present study was to compare the effect of concurrent training, based on an individual load-velocity ratio assessment, and endurance training alone on blood and metabolic biomarkers, body composition and fitness of adults with hypertension. One of the main findings of this study was that both groups, concurrent training and endurance training, showed improvements in blood biomarkers, reducing SBP, DBP, MAP, PP, RPP and RHR. However, the concurrent training group obtained greater reductions in SBP, DBP and MAP than the endurance training group, up to -12.8 mmHg, -6.8 mmHg and -8.6 mmHg respectively. The same dynamics was observed in PP. The results obtained in the present study, on the reduction of blood pressure levels, were significantly greater than those obtained in previous studies with this same training modality, despite the fact that the training frequency was lower. These improvements may be due to different mechanisms such as endothelium-dependent vascular function and structure and sympathetic nervous system regulation, which are altered and may contribute to blood pressure elevation (Gallo et al., 2021; Mancia & Grassi, 2014; Mancia et al., 2023). Endothelial dysfunction is a determinant factor in vascular function, and it is largely dependent on the bioavailability of nitric oxide (NO), which induces vessel relaxation and regulates blood pressure (Gamboa et al., 2007; Node et al., 1997). Strength training may act as a regulator of NO bioavailability by increasing vascular AMPK/PPARδ and suppressing endoplasmic reticulum stress, thereby improving and maintaining endothelial function (Cheang et al., 2017; Tian & Meng, 2019). These results may be in line with previous studies that showed how strength training significantly improved the endothelial function in different

population groups (Ashor et al., 2015; Zhang et al., 2021). In addition, this training modality may also improve vascular structure by increasing artery diameter and reducing vascular intima-media wall thickness (Spence et al., 2013). On the other hand, in patients with hypertension, it is common to find an overactivation of the sympathetic nervous system and a reduction in parasympathetic control (Fisher & Paton, 2012; Mancia & Grassi, 2014). This physiological imbalance can also be normalised and regularised by strength training as previous research has shown (Laterza et al., 2007; Trevizani et al., 2018).

In terms of body composition variables, lean mass, body fat, and waist circumference, both groups showed significant improvements as compared to the CG. Physical exercise induces changes in body composition through skeletal muscles, which are able to release hundreds of myokines into the bloodstream during muscle contraction that are able to interact with the muscle itself and with the rest of the body's organs, resulting in great health benefits (Pedersen, 2006; Pedersen & Saltin, 2015). These benefits include fat loss and increased muscle mass. The secretion of some of these myokines promotes lipolysis and fatty acid oxidation, and induces the darkening of white adipose tissue (Brandt & Pedersen, 2010; Pedersen, 2006). It is important to note that the participants who performed the concurrent training obtained greater reductions in abdominal perimeter than the participants who performed the endurance training. These results may be due to the fact that strength training favours visceral fat loss by promoting metabolic adaptations in the abdominal subcutaneous adipose tissue, with a significant increase in lipolysis in this area both during and after the training (Khalafi et al., 2021; Wewege et al., 2022).

Glucose values in both experimental groups were significantly reduced after the intervention versus the CG. This improvement could be due to the fact that exercise is able to improve insulin sensitivity starting from the first training session, as well as overall glucose homeostasis (Mul et al., 2015). Exercise can increase glucose-6-phosphate levels accompanying the increase in GLUT4, hexokinase, and glycogen synthase activity, leading to an increase in glucose tolerance and a decrease in blood glucose levels (Mul et al., 2015; Tian & Meng, 2019; Way et al., 2016).

With respect to the physical condition variables, the participants in both experimental groups showed improvements in both their strength and cardiorespiratory capacity. With regard to strength gains, these were due to the fact that training, regardless of the modality, is able to provoke structural (peripheral) and neural (central) physiological adaptations, given that in all the exercises, muscle action is required to overcome resistance (Badillo & Serna, 2002; González-Badillo et al., 2022). It is important to note that the concurrent training group obtained greater improvements in all the tests than the endurance training group. These results may be due to the specificity of the strength training, which provoked greater adaptations of the central nervous system thanks to a greater recruitment of motor units, their better synchronisation, and the frequency of the stimulus, as already shown in much of the literature (Del Vecchio et al., 2019; Enoka, 1997; Folland & Williams, 2007; Sale, 1988).

Finally, the cardiorespiratory capacity also improved significantly after completion of the exercise programmes in both groups. Exercise promotes adaptations in skeletal muscle such as increased mitochondrial biogenesis and capillary density, thereby improving the ability to transport and use oxygen to generate energy (Akimoto et al., 2005; Booth et al., 2015; Jung & Kim, 2014). Numerous studies have attributed a key role to peroxisome proliferator-activated receptor gamma coactivator 1α (PGC-1α) in these cardiovascular exercise-induced muscle adaptations (Akimoto et al., 2005; Baar et al., 2002; Halling & Pilegaard, 2020; Jung & Kim, 2014). Although there is a controversy in the literature that concurrent training may interfere with the adaptations induced by the different metabolic pathways, AMPK was activated by endurance training and m-TOR was activated by strength training. However, in this present study, it can be observed that the participants who performed the combined training showed greater improvements in VO_2peak than the participants who performed the endurance training. These results of concurrent training could be justified by the large adaptive reserve of sedentary subjects to any training programme. Previous work has shown that when a previously sedentary subject begins a concurrent training programme, the response to the two exercise modalities is positive and additive, promoting a generic adaptation in the absence of a true specificity of the training effect (Coffey & Hawley, 2017). Another important factor to consider is the low degree of effort involved in strength training, which would explain why the

possible interference would also be low, resulting in greater responses with respect to the maintenance of MHC IIX fibres (Pareja-Blanco, Rodríguez-Rosell, et al., 2017), which could be translated into an improved ability to transport and use oxygen, an increased ability to apply force and a significant improvement in physical fitness.

This study has some limitations that should be taken into account for future research, such as the total intervention time, possibly with longer periods of time more significant results could have been obtained in some of the variables. Another point to consider is the lack of a strength group in which the intensity and volume were not quantified through the speed of execution, but in the traditional way, through the percentage of 1RM and a determined number of repetitions. This would have allowed us to know the effects of the different training programs on blood pressure levels and to continue advancing in the improvement of cardiovascular health. Finally, another limitation was the daily intake of the participants, the diet could have been controlled by making a daily dietary record. Despite the limitations, this would be the first study conducted in an adult population with hypertension, in which the intensity and volume of strength training had been programmed through the velocity of execution, which allowed individualising the work stimulus for each participant with the greatest possible precision, something unknown to date in this population group. In addition, this quantification of the training load allowed the degree of fatigue reached by the participants to be similar throughout the intervention period. This study will provide new insights into the scientific community's multicomponent impact on adults with hypertension. This is the first study to apply a strength-speed training protocol based on training in this population. It also compares it with aerobic training. Controlling this variable is vital for injury prevention (McClean et al., 2024; Motlagh & Lipps, 2024), and the present study shows improvements in hemodynamic parameters, demonstrating reduced fatigue. This improves training control, enhances safety, and reduces the risk of injury.

The findings of the present study indicate that following a strength training programme, based on an individual load-velocity ratio assessment, combined with endurance training at a frequency of 2 days per week for 12 weeks, produces improvements in metabolic and blood biomarkers, body composition, and physical

fitness of adults with hypertension, with these adaptations being superior to those produced by endurance training alone, even though the latter showed improvements, but to a lesser extent.

5.11. METHODS

5.11.1. **Study Design**

A randomised control trial was conducted. A simple randomization method with the software Microsoft Excel (version 2016) was used to distribute subjects into the Experimental Group 1 (EG1) (n=25), Experimental Group 2 (EG2) (n=25), and Control Group (CG) (n=25). Based on blood pressure, a randomised sequence was generated. The group assignment was blinded to the examiner and staff who performed the statistical analysis. The trial design was recorded (22/06/2023) in ClinicalTrial.gov (Code: NCT05914870) and followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines and the Template for Intervention Description and Replication (TIDIER) checklist.

This randomized control trial obtained the approval by the Research Ethics Committee of the Universidad Católica de Murcia (CE062107), in accordance with the Declaration of Helsinki. The Informed Consent document was signed by all participants prior to the start of the study.

5.11.2. **Participants**

The study included 75 volunteers, 36 women and 39 men (54.45±6.72 years). Figure 1 shows a flowchart representing the Consolidated Standards of Reporting Trials.

The inclusion criteria were: a) adults with diagnosed hypertension and with follow-up by their primary care physician; b) being within the age range of 40-65 years old and c) not having exercised during the last year. The exclusion criteria were: a) subjects with osteoarticular or musculoskeletal problems that could interfere with the performance of daily activities; b) acute or chronic disease that could compromise the subject's autonomy and functional independence; or c) neurological problems. The participants were instructed not to modify their

lifestyle: eating habits and physical activity. The sample size and power calculations were performed using Rstudio 3.15.0 software. The significance level was set at α=0.05 and the power to 95% (1-β=0.95). The standard deviation was used according to the standard deviation for blood pressure from previous studies (Schroeder et al., 2019). A total of 10 mmHg in SBP and 5 mmHg in DBP were set as a minimum clinically significant change (Gorostidi et al., 2022). Considering a dropout rate of up to 9.57% (Stewart et al., 2005), 27 participants in each group needed to be enrolled. The final sample provided a power of 95% if found between and within a variance of 4.9 mmHg of SBP and 3.39 mmHg in DBP.

5.11.3. **Assessment**

Two researches conducted all pre-post intervention measurements under the same conditions. Two weeks before the initial evaluations, all participants were informed of the prerequisites for each of the tests.

Two assessment sessions were necessary, 48-72 hours apart from one another. The assessments were carried out in a laboratory with a standardised temperature of 24°C. The measurements were taken in the morning, between 8:00 and 13:00 hours from Monday to Saturday. Height was measured with a SECA 217 stadiometer (SECA, Germany). The Body Composition Analysis was performed with the Body Composition Analyser InBody 770 through the measurement method DSM-BIA (Bioelectric Impedance Multifrequency and Direct Segmental) (Buch et al., 2022; Lahav et al., 2021). Prior to the assessment, the participant was informed that they should come to the appointment fasting or at least 3 hours after the last meal; 30 min before the assessment, they should not have ingested any liquids; they should not have been to the toilet; they should not have drunk alcohol 48 hours before; and they should not wear any metal elements in contact with the skin (rings, bracelets or watches). For the measurement the participant completely cleaned his hands and feet completely with the InBody tissue and stood in front of the equipment; they climbed onto the InBody stepping barefoot on the foot plates and holding the hand electrodes, with arms outstretched without touching the sides of the body and without being allowed to speak or move until the end of the test.

Waist circumference was measured according to the ISAK protocol (Marfell Jones et al., 2006) with a non-elastic tape measure (SECA 200; SECA). The participant stood with their feet together, arms crossed over the chest and relaxed abdomen; the measurement was taken at the narrowest point of the waist at the end of a normal exhalation.

Haemodynamic parameters were assessed using the BPBIO-750 sphygmomanometer, clinically validated according to the ESH protocol (Hypertension, 2010). The measurement was performed on the left arm, supported and relaxed on the blood pressure monitor, with the cuff at the level of the heart. Three measurements were taken within 3 min of each other. The mean values of the measurements were taken as a reference (Stergiou et al., 2021).

Blood samples were taken by puncturing the cubital vein. The samples were stored in sterile blood tubes in refrigerated conditions (4-8° degrees Celsius (C)) for no longer than 4 hours and then sent to testing according to standardized procedures. Blood glucose was measured using an ultraviolet assay with hexokinase; total cholesterol (TC), high density lipoprotein (HD), and low-density lipoprotein (LDL) were measured using a homogeneous enzymatic colorimetric test, and triglycerides (TG) were measured using enzymatic assay (Cobas 8000 C702, Roche, Mannheim, Germany).

The manual grip force was measured with the Baseline manual hydraulic dynamometer. For the measurement, the participants had to remain seated on the chair with their back against it, feet on the floor, right elbow flexed at 90º, and the wrist in a neutral position. Then, they had to grip the dynamometer with their thumb upwards; once in the correct position, the subject squeezed the grip as tightly as possible for 3 seconds. The highest peak strength (kilograms (kg)) recorded between the two attempts was considered for analysis (Mathiowetz et al., 1985).

The assessment of lower and upper body strength was carried out through the velocity of execution in the concentric action by means of the Velowin optoelectronic encoder (Velowin v.1.7.232, Instruments and Sports Technology; Murcia, Spain) (Conceição et al., 2016; Sánchez-Medina & González-Badillo, 2011). In addition, the velocity of execution allowed for high precision programming of training intensity and volume. Two tests per body region were carried out, one of

progressive loads, to estime 1RM and determine the training load, and the other of loss of velocity in the set (VL%), to establish the number of repetitions, on a Multipower BH TR machine, and the exercises performed were the squat and the bench press (Conceição et al., 2016; Rodríguez-Rosell et al., 2020; Sánchez-Medina & González-Badillo, 2011). For reasons of standardization and safety, the concentric phase of each exercise was performed at the maximum possible velocity and the eccentric phase at a slow and controlled velocity, between 3-4 seconds in duration. The squat and bench press tests were performed in different sessions and their order was randomised. All participants performed 2-3 pre-test repetitions in the same evaluation session, they were instructed to move the barbell at the maximum possible speed in the concentric phase and in a slow and controlled manner in the eccentric phase.

For the progressive load test with the squat exercise, the participant stood with knees and hips extended, legs approximately shoulder-width apart and the Multipower bar resting on the upper back. The subject performed the parallel squat downwards in a continuous motion until reaching 80-90° of knee flexion, touching the reference bench, and immediately climbed back up to the starting position at the maximum possible velocity keeping the feet in contact with the ground (without jumping), although the heels could be lifted slightly (Escamilla, 2001; Sánchez-Medina et al., 2017). The initial external load for the squat exercise was set at 15kg for women and progressively increased individually with 5kg, 2.5kg and 1.25kg discs. For men, it was set at 25kg and progressively increased individually with 10kg, 5kg and 2.5kg discs. Both, males and females executed the exercise until reaching a mean propulsive velocity (MPV) between 0.76-0.68 $m \cdot s^{-1}$, which corresponds to 75%-80% 1 repetition maximum (1RM) in this exercise. In the test, 5 sets were performed, in the first set the participant performed 3 reps with a very light load which allowed them to move the bar at a lower velocity of 1.28 $m \cdot s^{-1}$ (less than 40% 1RM); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.28-1.21 $m \cdot s^{-1}$ (40%-45% 1RM); In the third set, he performed 3 reps with a medium load that allowed him to move the barbell between 1.14-1.00 $m \cdot s^{-1}$ (50%-60% 1RM); In the fourth set, they performed 2 reps with a medium-high load that allowed them to move the barbell between 0.92-0.84 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set he performed 1 rep with a high load that allowed them to shift the bar between 0.76-0.68$m \cdot s^{-1}$ (75%-80% 1RM). The velocity

loss (VL) test was performed 24 hours after the progressive load test. For this test, a medium workload was defined, the participant was allowed to move the barbell to 0.99 ± 0.02 $m \cdot s^{-1}$, assuming 60% of 1RM, and a low VL magnitude of 10% was set for the squat exercise. The test ended when the subject reached the prescribed VL% limit, regardless of the number of repetitions performed in the set (Morán-Navarro et al., 2019; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina et al., 2017). For the progressive load test with the bench press exercise, the participant was positioned lying on a horizontal bench with feet resting on the back bar of the Multipower to avoid lumbar arching; hands were placed on the non-slip area of the bar 5-7cm wider than shoulder width apart. The position of the bench was adjusted so that the bar was aligned with the chest line of each participant. During execution, the eccentric phase of each repetition was performed with controlled speed until the bar was 1-2cm above the chest, they stopped for 1s, to minimise the contribution of the stretch-shortening cycle, and then pushed the bar at maximum velocity. The initial external load for bench press exercise was set at 10kg for women and progressively increased individually with 5kg, 2.5kg and 1.25kg discs. For men, it was set at 20kg and progressively increased individually with 10kg, 5kg and 2.5kg discs. Both, males and females executed the exercise until reaching an MPV between 0.55-0.47$m \cdot s^{-1}$, which corresponds to 75%-80% 1RM in this exercise. For the test, 5 sets were performed, in the first set the participant performed 3 reps with a very light load which allowed them to move the bar at a lower speed of 1.13 $m \cdot s^{-1}$ (less than 40% 1RM); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.13-1.04 $m \cdot s^{-1}$ (40%-45% 1RM); In the third set, they performed 3 reps with a medium load that allowed him to move the barbell between 0.95-0.87 $m \cdot s^{-1}$ (50%-60% 1RM); In the fourth set, they performed 2 reps with a medium-high load that allowed them to move the barbell between 0.70-0.62 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set they performed 1 rep with a high load that allowed him to shift the bar between 0.55-0.47$m \cdot s^{-1}$ (75%-80% 1RM). The velocity loss test was performed 24 hours after the progressive load test. For this test, a medium workload was defined, which allowed the participant to move the barbell to 0.97±0.03 $m \cdot s^{-1}$, assuming 50% 1RM, and a low velocity loss magnitude of 15% was set. The test ended when the subject reached the prescribed VL% limit, regardless of the number of repetitions performed in the set (González-Badillo et al., 2017; Rodríguez-Rosell, Yáñez-

García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina & González-Badillo, 2011).

Cardiorespiratory capacity was assessed using a maximal effort test on the IC7 high-precision cycloergometer with a direct WattRate power meter and an exact magnetic resistance of 300 degrees. The steps lasted 2 min and the pedalling cadence was 70-80ppm. In the first 2 min, the subject pedalled at 50w, after which the load was increased by 25w every 2 min; the test ended when the participants voluntarily decided to stop due to fatigue that prevented them from continuing with the test (Marqueta et al., 2016). The test lasted between 10 and 15 minutes. The maximum working power was determined as the last 2 min step that the subject was able to complete without interruption, and the ACSM formula was used for the estimation of VO_2max (Ferguson, 2014). The following formula was used: VO_2max = (1.8 * workload (kg.m.min-1))/body weight (kg) + 3.5 + 3.5 (where one watt = 6.12 kg.m.min-1). For intensity control the heart rate (HR) was monitored at all times using the MyZone MZ-3 Heart Rate Monitor (Cuadros et al., 2017). To address the potential limitations of this method of HR monitoring, we simultaneously recorded the subjective perception of exertion (RPE) (Borg, 1998; Lea et al., 2022) every 10 min during the session, and monitored and recorded the training in watts at all times with the WattRate direct measurement potentiometer (Allen et al., 2019) via a computer installed in the cycloergometer, helping participants to achieve the prescribed work intensity for each training protocol. In addition, blood pressure and oxygen saturation were monitored during the stress test.

5.11.4. **Procedure**

The intervention period lasted 12 weeks, 2 days/week, with the sessions lasting 60 min each.

EG1 performed strength training, based on an individual load-velocity ratio assessment, combined with endurance training. The first phase was a warmup of 5 min of Nordic walking on an elliptical bike, joint mobility exercises, and dynamic stretching; and 2 sets of squat and bench press with a light weight. The main phase consisted of 20 min of strength work with a selection of 2 exercises: squat (60% 1RM) and bench press (50% 1RM). For both exercises, 3 sets were performed, with

a 3 min rest between sets and the number of repetitions individualised for each participant by the initial speed loss test; the average number of repetitions performed for the squat exercise was 8 repetitions and for the bench press exercise 7 repetitions (Table 4).

The initial absolute loads corresponding to 50% of 1RM in bench press and 60% of 1RM in squat were not modified throughout the intervention period, nor were the number of repetitions set for each participant. Regarding the selection of volume for each of the exercises used, and following a minimum stimulus criterion, we considered the scientific literature regarding the control of this variable by means of the loss of velocity in the sets (VL%), as a more precise way of establishing the degree of effort (Pareja-Blanco, Sánchez-Medina, et al., 2017; Rodríguez-Rosell, JYáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina & González-Badillo, 2011). In this way, it was determined that the same loss of velocity in the sets allows for a similar degree of effort or fatigue to be reached between subjects who performed a training protocol with the same relative intensity, although they performed different numbers of repetitions (González-Badillo et al., 2017; Rodríguez-Rosell et al., 2020). The analysis of the studies already carried out allowed establishing a VL of 25-30% in squat and 35-40% in bench press, as moderate-high degrees of effort beyond which the degree of fatigue begins to have important repercussions at a metabolic and mechanical level, causing a significant reduction in physical capacity and performance (González-Badillo et al., 2017; Rodríguez-Rosell et al., 2020; Sánchez-Medina & González-Badillo, 2011). In strength training, speed losses in the series of less than 20-30% in exercises such as squats or bench presses are associated with better physical fitness results. A speed loss in the set between 10-20% is sufficient to achieve significant physical condotion benefits, while losses greater than 30% are closer to muscle failure, which may not be optimal for a health improvement goal. To guarantee the use of a low training volume, for the intensity rates proposed in the present study, VL% was set at 10% for the squat exercise and 15% for the bench press in order to ensure improvements in physical condition and reduce potencial risks, given that the study population is sedentary.

In the last 20 min of the main phase, the participants performed continuous endurance training on a cycloergometer. The training intensity was programmed

using the Heart Rate Reserve (HRR) using Karvonen's formula (HRR = HRmax - HRrest); once the HRR was known, the prescribed intensity percentage was calculated (% HR= (HRR × % intensity) + HRrest) (Karvonen et al., 1957). As this was a sedentary population, and the exercise tolerance of each subject was unknown, a moderate intensity range was prescribed for the entire intervention, between 55% and 70% of their heart rate reserve (HRR), in order to achieve the metabolic adaptations already described in the scientific literature (Mølmen et al., 2025). Finally, the post-training phase included 10 min of cool down and static stretching.

As this was a sedentary population, and the exercise tolerance of each subject was unknown, a moderate intensity range was prescribed for the entire intervention, between 55% and 70% of their heart rate reserve (HRR), in order to achieve the metabolic adaptations already described in the scientific literature.

EG2 performed continuous endurance training. The warm-up was the same as EG1 except for the squat and bench press sets. In the main phase, they performed 40 min of continuous endurance training on a cycloergometer, taking into account the same protocol as in EG1. The post-workout phase was the same as EG1.

5.11.5 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 percentage were used for the qualitative variables. A two-way ANOVA analysis of variance with repeated measurements and Bonferroni's correction were used to compare the changes from the baseline between groups, evaluation time interaction, and evaluation time. To protect against a Type I error, Bonferroni's correction was used to achieve a $p = 0.005$ for statistical significance. The effect size was calculated using partial eta-squared ($\eta 2p$) for analysis of variance, and was defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30, large: ES ≥ 1.2; or very large: ES ≥ 2.0; an error of $p \leq 0.05$ is established (Hopkins et al., 2009). All analyses were based on intention-to-treat with an error of $p < 0.05$. The statistical analysis was performed using the statistical package SPSS 24.0 for Windows.

Figure 1

Consolidated Standards of Reporting Trials flow diagram.

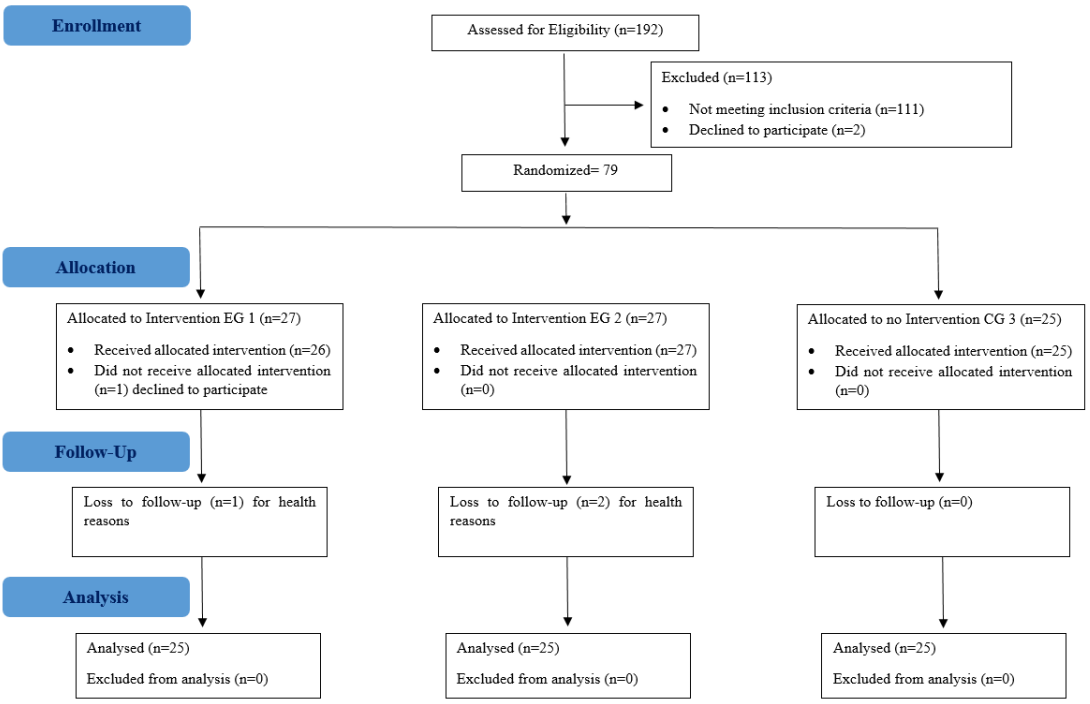


Table 1

Training monitoring results

	EG1			**EG2**		
	HR average	%HR max	RPE	HR average	%HR max	RPE
Week 1	118.88±15.88	66.56	3.20±1.41	117.75±13.61	66.75	3.21±1.22
Week 2	116.32±12.58	65.60	2.88±1.33	118.25±12.02	67.25	3.21±0.98
Week 3	118.12±11.50	66.84	3.20±1.08	118.21±14.02	67.25	3.33±1.09
Week 4	115.60±13.24	65.32	2.84±1.18	118.21±13.28	67.21	3.17±1.20
Week 5	115.92±14.75	65.68	3.00±1.26	118.83±13.35	67.50	3.37±1.06
Week 6	115.32±14.18	65.20	2.96±0.93	117.21±11.62	66.58	3.12±0.95
Week 7	115.84±12.72	65.12	2.84±1.03	119.79±13.38	68.13	3.46±1.18
Week 8	116.80±15.57	65.72	3.16±1.28	119.17±11.37	67.75	3.21±1.18
Week 9	119.36±13.39	67.16	3.16±1.14	121.33±11.62	68.75	3.38±1.31
Week 10	117.32±12.56	66.36	3.08±1.08	118.50±10.47	67.29	3.08±0.97
Week 11	120.00±16.03	67.80	3.52±1.33	122.04±11.72	69.42	3.54±1.22
Week 12	113.96±13.25	64.56	2.84±0.94	117.79±10.89	67.00	3.21±1.02

Table 2

Effect of combined training and endurance training on blood biomarker and body composition.

Outcome	Group	Pre-test (M±ED)	Post-test (M±ED)	Difference post-pre (M±ED)	p	95% CI (Mpost-Mpre)	Group*time interaction		
							F	Sig	ES
SBP (mmHg)	EG1	142.441±7.53	121.76±8.52	-21.68±1.43**##	<0.001	-24.52; -18.84	52.00	<0.001	0.59
	EG2	144.12±8.81	135.24±8.98	-8.88±1.43**	<0.001	-11.72; -6.04			
	CG	147.92±11.84	146.56±11.53	-1.36±1.43	0.343	-4.20; 1.48			
DBP (mmHg)	EG1	88.28±5.73	74.36±5.10	-13.92±1.08**##	<0.001	-16.067; -11.773	26.92	<0.001	0.43
	EG2	89.68±6.95	82.56±6.26	-7.12±1.08*	<0.001	-9.267; -4.973			
	CG	92.16±7.28	89.32±6.95	-2.84±1.08	0.01	-4.987; -0.693			
MAP (mmHg)	EG1	106.52±5.28	90.12±5.34	-16.40±1.00**##	<0.001	-18.393; -14.407	50.50	<0.001	0.58
	EG2	107.84±6.06	100.12±6.37	-7.72±1.00**	<0.001	-9.713; -5.727			
	CG	110.60±7.25	108.28±7.80	-2.32±1.00	0.023	-4.313; -0.327			
PP (mmHg)	EG1	55.16±7.49	47.40±7.68	-7.76±1.45**#	<0.001	-10.642; -4.878	10.43	<0.001	0.23
	EG2	54.44±10.08	52.68±7.17	-1.76±1.45	0.227	-4.642; 1.122			
	CG	55.76±11.32	57.20±8.52	1.44±1.45	0.323	-1.442; 4.322			

RPP	EG1	11254.00±1735.96	8507.64±1309.88	-2746.36±251.20**##	<0.001	-3247.117; -2245.603	30.94	<0.001	0.46
	EG2	11321.60±1442.08	9957.36±1358.10	-1364.24±251.20**	<0.001	-1864.997; -863.483			
	CG	11827.56±1474.97	11875.68±1132.23	48.12±251.20	0.849	-452.637; 548.877			
RHR	EG1	78.40±11.06	69.72±8.49	-8.68±1.68**	<0.001	-12.032; -5.328	8.99	<0.001	0.20
	EG2	78.80±11.03	73.72±9.35	-5.08±1.68*	0.003	-8.432; -1728			
	CG	80.00±8.23	81.28±8.07	1.28±1.68	0.449	-2.072; 4.632			
BMI (kg/m²)	EG1	27.43±4.88	27.26±4.57	-0.18±0.16	0.275	-0.495; 0.143	0.27	0.76	0.01
	EG2	32.75±5.09	32.56±5.06	-0.19±0.16	0.234	-0.511; 0.127			
	CG	31.91±5.00	31.87±5.10	-0.04±0.16	0.803	-0.359; 0.279			
LBM (Kg)	EG1	28.99±6.74	29.57±6.77	0.58±0.15**	<0.001	0.279; 0.881	7.55	<0.001	0.17
	EG2	30.84±6.80	31.35±6.81	0.51±0.15**	<0.001	0.207; 0.809			
	CG	30.56±5.98	30.39±5.92	-0.17±0.15	0.258	-0.473; 0.129			
BFP (%)	EG1	32.63±10.27	31.56±9.76	-1.07±0.34*	0.002	-1.739; -0.405	4.41	0.02	0.11
	EG2	39.43±8.04	38.47±8.14	-0.96±0.34*	0.005	-1.631; -0.297			
	CG	37.70±8.45	37.89±8.70	0.20±0.34	0.56	-0.471;0.863			
VF (cm²)	EG1	125.19±58.84	119.75±54.33	-5.44±2.13*	0.013	-9.68; -1.208	2.78	0.07	0.07
	EG2	183.40±58.34	178.28±58.00	-5.12±2.13*	0.018	-9.36; -0.888			

	CG	165.26±54.59	166.10±55.82	0.85±2.13	0.691	-3.388; 5.084			
Waist circumference (cm)	EG1	98.76±10.54	92.16±10.59	-6.60±0.84**#	<0.001	-8.265; -4.935	19.25	<0.001	0.35
	EG2	110.48±13.13	107.28±15.12	-3.20±0.84**	<0.001	-4.865; -1.535			
	CG	105.80±12.33	106.52±12.65	0.72±0.84	0.391	-0.945; 2.385			

Legend: SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MAP: Mean Arterial Pressure; PP: Pulse Pressure: RPP: Rate Pressure Product; RHR: Resting Heart Rate; BMI: Body Mass Index; LBM: Lean Body Mass; BFP: Body Fat Percentage; VF: Visceral Fat; *Significantly different from CG value at the $p < 0.05$ level; ** Significantly different from CG value at the $p < 0.01$ level. # = Significantly different from other EG $p < 0.05$ level; ## = Significantly different from other EG value at the $p < 0.01$ level.

Table 3

Effect of combined training and endurance training on metabolic biomarkers, and physical fitness

Outcome	Group	Pre-test (M±ED)	Post-test (M±ED)	Difference post-pre (M±ED)	p	95% CI (Mpost-Mpre)	Group*time interaction		
							F	Sig	ES
CT (mg/dl)	EG1	199.72±30.11	192.08±29.21	-7.64±5.52	0.17	-18.636; 3.356	6.08	<0.001	0.15
	EG2	190.12±41.09	183.12±24.57	-7.00±5.52	0.209	-17.996; 3.996			
	CG	191.76±28.51	208.00±29.89	16.24±5.52	0.004	5.244; 27.236			
HDL (mg/dl)	EG1	54.44±9.93	55.32±11.29	0.88±1.07	0.413	-1.25; 3.01	0.85	0.43	0.02
	EG2	48.04±7.06	49.72±10.25	1.68±1.07	0.12	-0.45; 3.81			
	CG	48.76±11.10	48.48±12.49	-0.28±1.07	0.794	-2.41; 1.85			
LDL (mg/dl)	EG1	120.62±24.78	114.14±24.55	-6.47±5.01	0.201	-16.461; 3.517	6.34	<0.001	0.15
	EG2	116.32±36.92	108.22±23.88	-8.10±5.01	0.111	-18.085; 1.893			
	CG	116.82±23.25	131.34±31.29	14.52±5.01	0.005	4.531; 24.505			
	EG1	122.32±59.16	113.72±43.21	-8.60±8.08	0.291	-24.726; 7.526	2.134	0.126	

TG (mg/dl)	EG2	126.16±51.06	124.88±39.08	-1.280±8.089	0.875	-17.406; 14.846			0.06
	CG	133.44±64.33	147.96±79.97	14.520±8.089	0.077	-1.606; 30.646			
Glucose (mg/dl)	EG1	98.16±14.69	91.36±10.77	-6.800±1.366**	<0.001	-9.524; -4.076	15.99	<0.001	0.31
	EG2	106.84±13.44	99.84±13.77	-7.000±1.366**	<0.001	-9.724; -4.276			
	CG	97.24±22.48	99.80±19.94	2.560±1.366	0.65	-0.164; 5.284			
Handgrip RA (Kg)	EG1	32.36±10.20	34.52±11.45	2.16±0.59**	<0.001	0.983; 3.337	4.50	0.01	0.11
	EG2	34.40±8.36	36.80±10.30	2.40±0.59**	<0.001	1.223; 3.577			
	CG	32.64±9.63	32.76±9.76	0.12±0.59	0.84	-1.057; 1.297			
Handgrip LA (Kg)	EG1	30.00±9.61	31.96±11.10	1.96±0.59**	0.001	0.787; 3.133	6.43	<0.001	0.15
	EG2	32.44±8.06	35.56±11.04	3.12±0.59**	<0.001	1.947; 4.293			
	CG	30.20±8.18	30.36±8.22	0.16±0.59	0.786	-1.013; 1.333			
1RM (UB)	EG1	46.24±23.68	65.12±30.34	-23.12±2.31**##	<0.001	-27.715; -18.525	0.81	0.45	0.02
	EG2	52.08±21.08	61.16±25.30	-26.04±2.31**	<0.001	-30.635; -21.445			
	CG	54.24±24.27	52.20±23.20	-27.12±2.31	<0.001	-31.715; -22.525			
	EG1	0.96±.03	1.20±.06	0.237±0.013**##	<0.001	0.211; 0.263	119.48		

Upper limb MPV (m/s 50%)	EG2	0.97±.02	1.08±.07	0.112±0.013**	<0.001	0.086; 0.139		<0.001	0.77
	CG	0.97±.02	0.92±.04	-0.050**±0.013	<0.001	-0.077; -0.024			
1RM (LB)	EG1	73.08±35.12	98.32±41.42	-29.23±2.82**#	<0.001	-34.856; -23.608	0.26	0.77	0.01
	EG2	74.48±38.23	91.80±42.49	-29.79±2.82**	<0.001	-35.416; -24.168			
	CG	79.92±32.18	76.44±30.73	-31.97±2.82	<0.001	-37.592; -26.344			
Lower limb MPV (m/s 60%)	EG1	0.99±.02	1.21±.05	0.225±0.014**#	<0.001	0.197; 0.253	98.01	<0.001	0.73
	EG2	0.99±.02	1.15±.07	0.161±0.014**	<0.001	0.133; 0.189			
	CG	0.99±.02	0.95±.05	-0.039±0.014	0.006	-0.067; -0.011			
VO2p (ml/kg/min)	EG1	25.09±3.82	30.87±4.41	5.78±0.34**#	<0.001	5.108; 6.452	87.68	<0.001	0.71
	EG2	22.18±4.33	26.78±5.29	4.60±0.34**	<0.001	3.929; 5.274			
	CG	21.62±3.58	21.44±3.58	-0.18±0.34	0.586	-0.857; 0.488			

WATT	EG1	127±30.55	167±34.40	40±2.36**	<0.001	35.29; 44.71	98.33	<0.001	0.73
	EG2	125±35.36	162±40.26	37±2.36**	<0.001	32.29; 41.71			
	CG	117±32.05	115±29.76	-2±2,36	0.4	-6.71; 2.71			

Legend: CT: Total Cholesterol; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; TG: Triglycerides; RA: right arm; LA: left arm; 1RM: Maximum Repetition; UL: Upper Limb; LL: Lower Limb; MPV: mean propulsive velocity; VO2p: Peak oxygen consumption; *Significantly different from CG value at the $p < 0.05$ level; ** Significantly different from CG value at the $p < 0.01$ level. # = Significantly different from other EG $p < 0.05$ level; ## = Significantly different from other EG value at the $p < 0.01$ level.

Table 4

Description of the 5-set protocol

Set	Load	Repetitions	1RM	Squat exercise Speed	Bench press Speed
1	Very light	3	<40%	<1.28 $m \cdot s^{-1}$	<1.13 $m \cdot s^{-1}$
2	Light	3	40%-45%	1.28-1.21 $m \cdot s^{-}$	1.13-1.04 $m \cdot s^{-1}$
3	Medium	3	50%-60%	1.14-1.00 $m \cdot s^{-1}$	0.95-0.87 $m \cdot s^{-1}$
4	Medium-high	2	65%-70%	0.92-0.84 $m \cdot s^{-1}$	0.70-0.62 $m \cdot s^{-1}$
5	High	1	75%-80%	0.76-0.68$m \cdot s^{-1}$	0.55-0.47$m \cdot s^{-1}$

Vc – ESTUDIO 3:
MODERATE INTENSITY CONTINUOUS TRAINING, COMBINED MODERATE-INTENSITY CONTINUOUS TRAINING VS COMBINED HIGH-INTENSITY INTERVAL TRAINING IN ADULTS WITH HYPERTENSION: RANDOMIZED CONTROLLED TRIAL

VC - ESTUDIO 3: Effectiveness of combined training based on an individual load-velocity ratio assessment versus endurance training: randomized control trail in adults with hypertension.

5.12. ABSTRACT

Background and purpose: Despite all efforts to treat hypertension, it is still responsible for 10.8 million deaths annually. The aim of this study was to compare the effects of continuous moderate-intensity training, strength training combined with continuous moderate-intensity training and strength training combined with highintensity interval training in adults with high blood pressure. Methods: A 12-week randomized control trial was performed. A total of 100 volunteers, 51 women and 49 men with hypertension participated. The sample was randomly assigned into three intervention groups and one control group. Results: All intervention groups significantly improved their hemodynamic parameters, body composition, lipid profile, glucose, and physical fitness as compared to the control group. Both combined training groups showed greater improvements than the moderate-intensity continuous training group. However, the strength group combined with the moderate-intensity continuous group showed the greatest benefits in systolic, diastolic and mean arterial pressure, of − 13.4 mmHg, − 6.8 mmHg and − 8.9 mmHg respectively, abdominal circumference, upper and lower limb strength and VO_2peak, versus the continuous moderate-intensity group; it also achieved greater reductions in systolic and mean blood pressure, up to − 6.8 mmHg and 4.3 mmHg respectively, than the strength group combined with the high intensity interval group. Conclusion: Performing a strength training program combined with continuous moderate intensity training, 2 days per week for 12 weeks, produces significant improvements in cardiometabolic biomarkers, body composition, and physical condition of adults with hypertension, with these adaptations being superior to those produced by continuous moderate-intensity training and strength training combined with high-intensity intervallic training.

5.13. INTRODUCTION

Hypertension is a chronic, virtually asymptomatic disorder that deteriorates the quality of blood vessels and can lead to target organ damage if not diagnosed early and properly controlled. It remains the most prevalent modifiable risk factor worldwide, and is responsible for more than 10 million deaths per year from cardiovascular disease (Mensah et al., 2023; Vaduganathan et al., 2022). In this sense, hypertension is considered at 140 mmHg systolic blood pressure (SBP) and 90 mmHg diastolic blood pressure (DBP); although an optimal control is below 130 mmHg and 85 mmHg respectively (Mancia et al., 2023). An active lifestyle is essential to address this disorder, as exercise acts as a drug that can prevent and treat many non-communicable diseases, including hypertension (Momma et al., 2022; Pedersen & Saltin, 2015). Moderate-intensity continuous training (MICT) is a priority for this population, according to the main clinical guidelines in cardiology and hypertension, with a minimum of 3 days/week and with a volume of 150–300 min/week at moderate intensity or 75–150 min/week at vigorous intensity (Charchar et al., 2024; Pelliccia et al., 2020; Whelton et al., 2018a), to achieve reductions in SBP from − 4.9 to − 12 mmHg and DBP from − 3.4 to − 5.8 mmHg (Hanssen et al., 2022; Whelton et al., 2018a). Furthermore, the inclusion of strength training at least 2 days/week is recommended to benefit from the health improvements provided by this modality (Kaminsky et al., 2022), including reductions in SBP from − 3.0 to − 4.7 mmHg and DBP from − 3.2 to − 3.8 mmHg (Charchar et al., 2024; Pelliccia et al., 2020); Some of these guidelines also specify a total of 8–10 exercises per session involving large muscle groups and performing 8–12 repetitions per exercise (Whelton et al., 2018a). These exercise guidelines do not include strength training combined with MICT in the same training session. However, different scientific publications have shown significant improvements in SBP and DBP levels with these training modalities (Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Schneider et al., 2023); Nevertheless, despite the benefits of combined training, further research is needed to establish dose-response relationships (Albalawi et al., 2017; López-Ruiz et al., 2023). Another training modality that has also been shown to improve blood pressure levels is high-intensity interval training (HIIT) (Costa et al., 2018; Li et al., 2022; Ramos et al., 2015; Way et al., 2019). Recently, this training modality, because

of its time efficiency and the growing evidence available, has been proposed as an alternative to MICT (Costa et al., 2018; Li et al., 2022; Way et al., 2019). While this modality alone has shown similar improvements in blood pressure levels (Carpes et al., 2022; Costa et al., 2018; Li et al., 2022), even higher in diurnal SBP or vascular function than MICT for the control of hypertension, according to recent meta-analyses (Carpes et al., 2022; Costa et al., 2018; Li et al., 2022; Ramos et al., 2015; Way et al., 2019), little research has combined strength work with HIIT in this population group (Alvarez et al., 2024; Kazemi et al., 2023), even though this tool may provide greater cardiometabolic health benefits.

On the other hand, the programming of training is a complicated task, and even more so when it comes to programming the degree of effort for strength improvement. In the literature that can be found on strength training and hypertension, strength has been assessed by performing 1RM (one-repetition maximum) tests, a method considered the gold standard, but which involves an excessive, inaccurate and even harmful effort (Badillo & Serna, 2002; González-Badillo et al., 2022); and for the volume of work, a fixed number of repetitions has been determined for all participants, resulting in a different degree of effort for each of them, as has been shown in previous work (Badillo & Serna, 2002; González-Badillo et al., 2022; Rodríguez-Rosell et al., 2020). Until recently, it was difficult to truly know the relative intensity at which one was working, and thus the intensity at which a certain effect was produced. This was solved when the speed of execution emerged, a tool that represents a paradigm shift in the field of training by providing accurate information on the programmed load and the effects produced by it (Badillo, 2017; González-Badillo & Sánchez-Medina, 2010; Sánchez-Medina & González-Badillo, 2011). Currently, a large number of studies can be found with different population groups, in which the speed of execution has been used for the dosage of the training load; young men (Sánchez-Medina & González-Badillo, 2011), multiple sclerosis patients (Andreu-Caravaca et al., 2020), older women (Marcos-Pardo et al., 2019), or cancer survivors (Díez-Fernández et al., 2023). However, there are no contributions from the measurement of movement velocity in cardiovascular pathology, and more specifically in hypertension. One of the main problems with previous works is the lack of rigor in training programming; intensity and volume were not measured as accurately as possible, and it is therefore not possible to know whether the participants underwent the

same amount of training, with the same relative intensity and the same degree of fatigue. Therefore, the aim of the present study was to compare the effects of different individualized training programs: continuous moderateintensity training, strength training combined with continuous moderate-intensity training, and strength training combined with highintensity interval training, in adults with arterial hypertension.

5.14. MATERIALS AND METHODS

5.14.1. **Study design**

A randomized controlled clinical trial with several simultaneous study branches was conducted; the study was single-blind, longitudinal, and prospective. To distribute subjects into experimental group 1 (EG1), experimental group 2 (EG2), experimental group 3 (EG3), and control group (CG) a simple randomization method with the Microsoft Excel software (version 2016) was used. Four groups were established based on blood pressure values, after which a randomized sequence was generated using simple randomization. The group assignment was blinded to the examiner and staff who performed the statistical analysis. This research followed the guidelines from the Consolidated Standards of Reporting Trials (CONSORT) statement, and the Template for Intervention Description and Replication (TIDieR) checklist. The trial design was registered at ClinicalTrial.gov (Code: NCT05914870).

In accordance with de Declaration of Helsinki, this randomized control trial obtained the approval of the Research Ethics Committee of the Universidad Católica de Murcia (CE062107). The Informed Consent document was signed by all participants prior to the start of the study.

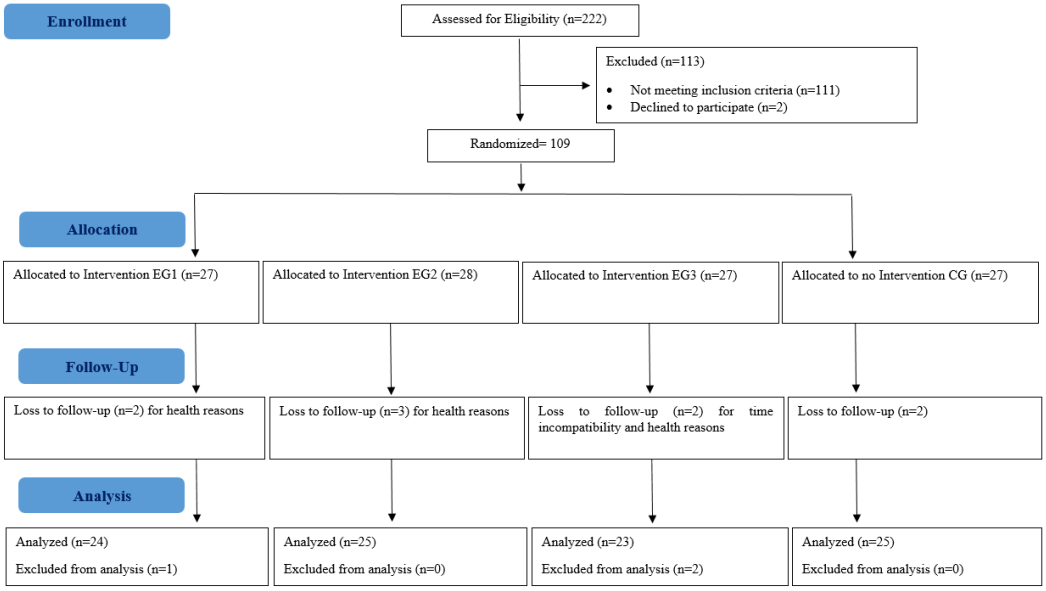
5.14.2. **Participants**

A total of 100 volunteers participated, 51 women and 49 men, all of them with hypertension, a mean age 54 years, and previously sedentary. The sample was randomly assigned into three experimental and one control group: EG1, moderate-intensity continuous training or MICT, (n = 24); EG2, strength training combined

with MICT, (n = 25); EG3, strength training combined with HIIT, (n = 23); and CG, control group, (n = 25) (see Fig.1).

Figure 1

Flow diagram



The inclusion criteria were: a) adults with diagnosed hypertension and with follow-up by their primary care physician; b) age range 40–65 years; (c) not engaged in at least 150 min of moderate physical activity per week or 75 min of vigorous physical activity per week or a combination of both during the past 12 months. The exclusion criteria were: a) subjects with osteoarticular or musculoskeletal problems that conditioned the development of the intervention; b) uncontrolled or traininglimiting cardiometabolic diseases such as heart disease, unstable coronary artery disease, heart failure, renal failure, diabetes, or morbid obesity; c) neurological problems; d) cognitive impairment that hinders the understanding and performance of the training; e) subjects who are dependent in the performance of daily activities; or f) pregnant women. Participants were instructed not to change their eating habits. The sample size and power calculations were performed using Rstudio 3.15.0 software. The significance level was set at $\alpha = 0.05$ and the power to

95 % (1-β = 0.95). The standard deviation used was according to the standard deviation for blood pressure found in previous studies (Schroeder et al., 2019) [34]. A minimum clinically significant change of a total of 10 mmHg in SBP and 5 mmHg in DBP was considered (Gorostidi et al., 2022). With a dropout rate of up to 9.57 % (Stewart et al., 2005), the aim was to enroll at least 26 participants in each group. The final sample provided a power of 95 % if found between and within a variance of 4.6 mmHg of DBP and 3.2 mmHg in DBP.

5.14.3. **Assessment tools and protocols**

The pre-post intervention measurements were carried out in the morning, between 8:00 and 13:00 h, by two researchers. They were carried out in a laboratory at a temperature of 24 ◦C, in two different assessment sessions, with a difference of 48–72 h between them and always under the same conditions. The height of the participants was measured with a SECA 217 stadiometer (SECA, Germany). Body Composition was assessed with the InBody 770 analyzer using the DSMBIA measurement method (Multifrequency and Direct Segmental Bioelectrical Impedance) (Buch et al., 2022; Lahav et al., 2021). The analysis was performed on an empty stomach, without drinking liquids 30 min before the test, without drinking alcohol 48 h before the test and without wearing metallic elements in contact with the skin such as chokers, rings, belts, etc. For the assessment, the subject wiped their hands and feet with the InBody tissue, then climbed forwards onto the equipment, placing their feet on the plates, and grasping the electrodes with their hands with arms extended away from the sides of the body, without speaking and without moving until the end of the test.

Abdominal girth was measured with a non-elastic tape measure (SECA 200; SECA) according to the ISAK protocol (Marfell Jones et al., 2006); standing with feet together, arms crossed on the chest and abdomen relaxed. The measurement was taken at the narrowest part of the waist after a normal exhalation.

The evaluation of the hemodynamic parameters, SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), PP (pulse pressure) and RPP (rate pressure product), was performed with the BPBIO-750 sphygmomanometer (Hypertension, 2010). For the test, the participants, after sitting for 5 min before the measurement, placed the left arm relaxed and supported

on the blood pressure monitor, with the cuff at the level of the heart, their back supported, legs parallel without crossing and in silence during the test. Three measurements were taken 3 min apart, and the average of the last two measurements was taken as the reference value (Stergiou et al., 2021).

Blood chemistry analyses were performed from 8:00 to 9:00 a.m., after a minimum fasting period of 10 h. Samples were stored in sterile tubes under refrigeration (4–8 ◦C) for a maximum of 4 h, and then analyzed according to standardized procedures. Total cholesterol (TC), high-density lipoproteins (HDL), and low-density lipoproteins (LDL), were measured by a homogeneous enzymatic colorimetric assay, while triglycerides (TG) were measured by an enzymatic assay. (Cobas 8000C702, Roche, Mannheim, Germany); and glucose by an ultraviolet hexokinase assay (Cobas 8000C702, Roche, Mannheim, Germany).

The manual hydraulic dynamometer Baseline was used to assess the manual gripping force. The test was performed with the participant seated on a chair, back supported, feet on the floor, right elbow flexed at 90◦, and holding the dynamometer with the wrist in neutral position with the thumb upwards; on command, the subject squeezed the grip as hard as possible for 3 s. The same procedure was repeated with the left hand. Two measurements were made with both hands and the highest maximum force (kg) of the two attempts was considered (Mathiowetz et al., 1985).

For the assessment of the maximum upper and lower body strength and the programming of the training, different tests were carried out using the speed of execution in the concentric motion with the Velowin optoelectronic encoder (Velowin v.1.7.232, Instruments and Sports Technology; Murcia, Spain) (González-Badillo & Sánchez-Medina, 2010; Sánchez-Medina & González-Badillo, 2011). Two tests were carried out per body region on the Multipower BH TR machine, one of progressive loads, and the other of velocity loss in the set (%VL); the exercises performed were the squat and the bench press (Badillo, 2017; González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2017; Sánchez-Medina & González-Badillo, 2011). The tests were carried out in different sessions, 24 h apart, and before starting the tests, the participant underwent a standardized general warm-up.

For the technical execution of the progressive load test in the squat exercise, the protocol described in previous studies was followed (Escamilla, 2001; Sánchez-

Medina et al., 2017). The initial external load for the squat exercise was set at 15 kg for women and was progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs until a mean propulsive velocity (MPV) between 0.76-0.68 $m \cdot s^{-1}$ was reached, which corresponds to 75%-80% 1RM in this exercise; for men was set at 25 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs until an MPV between 0.76-0.68 $m \cdot s^{-1}$ was reached, which corresponds to 75%-80% 1RM in this exercise. In the test 5 sets were performed, in the first set the participant performed 3 reps with a very light load that allowed him to move the bar at a speed <1.28 $m \cdot s^{-1}$ (<40% 1RM); in the second set he performed 3 reps with a light load that allowed him to move the bar between 1.28-1.21 $m \cdot s^{-1}$ (40%-45% 1RM); in the third set he performed 3 reps with a medium load that allowed him to move the bar between 1.14-1.00 $m \cdot s^{-1}$ (50%-60% 1RM); in the fourth set he performed 2 reps with a medium-high load that allowed him to move the bar between 0.92-0.84 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set he performed 1 rep with a high load that allowed him to move the bar between 0.76-0.68 $m \cdot s^{-1}$ (75%-80% 1RM) (Andreu-Caravaca et al., 2020; Conceição et al., 2016; Díez-Fernández et al., 2023; González-Badillo & Sánchez-Medina, 2010; Marcos-Pardo et al., 2019). The velocity loss test was performed 24 hours after the progressive load test. For this test, a workload was defined that allowed the participant to move the bar at 0.99 ± 0.02 $m \cdot s^{-1}$, assuming 60% of 1RM, and a velocity loss magnitude of 10% was established. The test ended when the subject reached the prescribed %VL limit, regardless of the number of repetitions performed in the series (Morán-Navarro et al., 2019; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020).

For the technical execution of the progressive load test in the bench press exercise, the protocol described in previous studies was followed (Díez-Fernández et al., 2023; Marcos-Pardo et al., 2019). The initial external load for the bench press exercise was set at 10 kg for the women and was progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs until a MPV between 0.55-0.47 $m \cdot s^{-1}$ was reached, which corresponds to 75%-80% 1RM in this exercise; for men was set at 20 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs until an MPV between 0.55-0.47 $m \cdot s^{-1}$ was reached, which corresponds to 75%-80% 1RM in this exercise. For the test 5 sets were performed, in the first set the participant performed 3 reps with a very light load that allowed him to move the bar at a speed <1.13 $m \cdot s^{-1}$ (<40%); in the second set he performed 3 reps with a light

load that allowed him to move the bar between 1.13-1.04 $m \cdot s^{-1}$ (40%-45% 1RM); in the third set he performed 3 reps with a medium load that allowed him to move the bar between 0.95-0.87 $m \cdot s^{-1}$ (50%-60% 1RM); in the fourth set he performed 2 reps with a medium-high load that allowed him to move the bar between 0.70-0.62 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set he performed 1 rep with a high load that allowed him to move the bar between 0.55-0.47 $m \cdot s^{-1}$ (75%-80% 1RM) (Andreu-Caravaca et al., 2020; González-Badillo & Sánchez-Medina, 2010; Marcos-Pardo et al., 2019). The velocity loss test was performed 24 h after the progressive load test. A workload was defined that allowed the participant to move the bar at 0.97 ± 0.03 $m \cdot s^{-1}$, assuming 50% 1RM, and a magnitude of velocity loss of 15% was established. The test ended when the subject reached the prescribed %VL limit, regardless of the number of repetitions performed in the series (González-Badillo et al., 2017; Sánchez-Medina & González-Badillo, 2011).

Cardiorespiratory fitness was assessed with the IC7 cycloergometer, with a high-precision potentiometer with a direct WattRate measurement and an accurate magnetic resistance of 300◦. For the adjustment of the bicycle, the protocol described in previous studies was followed (Gómez-Puerto et al., 2008). The test consisted of a clinical step test with progressive loads; the steps lasted 2 min and the pedaling cadence was between 70 and 80 bpm. In the first 2 min, the subject pedaled at 50 W, then the load was increased by 25 W every 2 min; the test ended when the participant decided to stop voluntarily due to fatigue (Marqueta et al., 2016). The maximum working power was established as the last 2 min step that the subject was able to complete. The VO_2max was estimated using the formula described by the ACSM (Ferguson, 2014): VO_2max = (1.8 *workload (kg.m.min-1))/body weight (kg) + 3.5 + 3.5 (where 1 W = 6.12 kg m.min-1).

5.14.4. **Procedure**

The intervention period lasted 12 weeks, the training frequency was 2 days/week (24 sessions) and the length of time per session was 60 min. EG1 performed a MICT session starting with 10 min of standardized general warm-up, 5 min of Nordic walking on an elliptical trainer, joint mobility exercises, and dynamic stretching. In the main phase, they performed 40 min of continuous aerobic endurance training on a cycloergometer, without breaks, maintaining the

same intensity range throughout the session; the intensity was increased every 4 weeks, from weeks 1–4 they worked at 55%–60 % heart rate reserve (HRR), from weeks 5–8 at 60%–65 % HRR, and from weeks 9–12 at 65%–70 % HRR. Finally, a 10 min post-workout phase with a cool down and static stretching took place.

EG2 performed strength training, based on an individual loadvelocity ratio assessment, combined with MICT. The session started with 10 min of standardized general warm-up, 5 min of Nordic walking on the elliptical machine, joint mobility exercises, and dynamic stretching. Finally, a more specific warm-up was performed. The participants performed 2 sets of each exercise, squat and bench press, only with the weight of the bar (5 kg); the first set consisted of 8–10 reps and the second set of 6–8 reps; the rest between sets was 2 min. The main training phase was divided into two 20-min blocks. During the first 20 min, they performed 2 strength exercises that reproduced basic motor actions. The first exercise was a lower hemisphere push (squat) with an intensity of 60 % of their 1RM; 3 sets were performed with the number of repetitions individualized for each subject using the initial speed loss test, and the rest between sets and between exercises was 3 min. The second exercise was a bench press at an intensity of 50 % of their 1RM. Regarding the selection of volume, the analysis of previous studies indicated a %VL of 25–30 % in squat and 35–40 % in bench press, as a medium-high effort value above which the degree of fatigue begins to increase, causing a significant decrease in performance (González-Badillo et al., 2017; Rodríguez-Rosell et al., 2020; Sánchez-Medina & González-Badillo, 2011).

Following a minimum stimulus criterion, in order to guarantee a low training volume, and considering the intensities proposed in this study, a 10 % %VL was established for the squat exercise and 15 % for the bench press. In the last 20 min of the main phase, the participants performed continuous moderate-intensity training on a cycloergometer; the intensity of the training increased every 4 weeks. Thus, from weeks 1 to 4, they trained at 55%-60 % HRR, from weeks 5 to 8, at 60%-65 % HRR, and from weeks 9 to 12, at 65%-70 % HRR. Finally, a 10 min post-training phase with cool down and static stretching took place.

EG3 performed strength training, based on an individual loadvelocity ratio assessment, combined with HIIT. This group performed the same warm-up protocol and the first 20 min of the main phase as EG2. In the last 20 min of the

main phase, they performed high-intensity interval training on a cycloergometer. Following the review of previous studies, and the lack of a standardized protocol for this training modality in adults with hypertension (Costa et al., 2018; Li et al., 2022), a work-recovery ratio of 1:1, 2 min work: 2 min active recovery was established following previous work in cardiac rehabilitation and cardiovascular pathology (Cardozo et al., 2015; Warburton et al., 2005; Yue et al., 2022). In addition, based on the European Society of Cardiology (ESC) classification of aerobic training intensity from maximal ergometry [6], an intensity of 80–85 % HRR was determined for the training time, and 55%–60 % HRR for the active recovery time. The review of the latest ESC documents allowed for the following ranges of intensity: 85 % very high intensity HRR (Hansen et al., 2021; Pelliccia et al., 2020). Training intensities were not modified during the intervention. Finally, a 10 min post-training phase with a return to calm and static stretching took place. The heart rate was monitored using the MyZone MZ-3 Heart Rate Monitor, which allowed the HR to be monitored at all times. In addition, the subjective rate of perceived exertion (RPE) was recorded simultaneously (Borg, 1998), as well as the training in watts, with the WattRate direct measurement potentiometer (Allen et al., 2019), by means of a computer integrated in the cycloergometer.

5.14.5. **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. A twoway analysis of variance (ANOVA) with repeated measurements and Bonferroni's correction will be used to compare the changes from the baseline between groups, the evaluation time interaction, and evaluation time. 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 ($\eta 2p$) for analysis of variance, and will be defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30, large: ES ≥ 1.2; or very large: ES ≥ 2.0. Lastly, an error of $p \leq 0.05$ was used (Hopkins et al., 2009). All analyses were based on intention-to-treat with an error of $p < 0.05$. The statistical analysis was performed using the statistical package SPSS 24.0 for Windows.

5.15. RESULTS

Table 1 shows the characteristics of the sample, and Tables 2 and 3 show the pre-post intervention results of EG1, EG2, EG3, and CG. In addition, group * time interaction is also presented.

Table 1

Characteristic of the sample

Variable		**% (n) or X±SD**
Sex	Female	51.54 (50)
	Male	48.45 (47)
Age		54.17±6.70
Marital Status	Married	87.00 (87)
	Single	11.00 (11)
	Widow	2.00 (2)
Occupation	Full-Time Worker	49.00 (49)
	Part-Time Worker	4.00 (4)
	Unemployed	16.00 (16)
	Self-Employed	10.00 (10)
	Retired	21.00 (21)
Education level	No Education	9.00 (9)
	Elementary School	32.00 (32)
	Secondary School	16.00 (16)
	High School	25.00 (25)
	University Education	18.00 (18)
Living Status	Living with Someone	87.00 (87)
	Living Alone	13.00 (13)

Table 2

Effect of multicomponent training and cardiovascular training on blood biomarker and body composition

Outcome	Group	Pre-test (M±ED)	Post-test (M±ED)	No Adjusted			Group * time interaction		
				Difference post-pre (M±ED)	p	95% CI (Mpost-Mpre)	F	Sig	ES
SBP (mmHg)	EG1	144.46±8.83	136.17±7.86	-8.29±1.46$^{*,\#,\#\#}$	<0.001	-11.20; -5.38	6.00	<0.001	0.54
	EG2	143.44±7.53	121.76±8.52	-21.68±1.43$^{*,**,\#\#}$	<0.001	-24.53; -18.82			
	EG3	143.87±8.49	128.96±10.40	-14.91±1.49$^{*,**,\#}$	<0.001	-17.88; -11.94			
	CG	147.92±11.83	146.56±11.52	-1.36±1.43$^{**,\#,\#\#}$	0.346	-4.21; 1.49			
DBP (mmHg)	EG1	90.00±6.90	82.92±6.12	-7.08±1.10$^{*,\#}$	<0.001	-9.27; -4.89	9.46	<0.001	0.38
	EG2	88.28±5.72	74.36±5.09	-13.92±1.08*,**	<0.001	-16.06; -11.77			
	EG3	88.30±6.98	77.61±7.91	-10.69±1.12*	<0.001	-12.93; -8.45			
	CG	92.16±7.28	89.32±6.95	-2.84±1.08$^{**,\#,\#\#}$	0.01	-4.98; -0.69			
MAP (mmHg)	EG1	108.17±5.96	100.67±5.87	-7.50±1.00$^{*,\#,\#\#}$	<0.001	-9.49; -5.50	7.06	<0.001	0.54
	EG2	106.52±5.27	90.12±5.34	-16.40±0.98$^{*,**,\#\#}$	<0.001	-18.35; -14.44			
	EG3	106.78±6.90	94.74±7.85	-12.04±1.02$^{*,**,\#}$	<0.001	-14.08; -10.00			
	CG	110.60±7.25	108.28±7.80	-2.32±0.98$^{**,\#,\#\#}$	0.021	-4.27; -0.36			
PP (mmHg)	EG1	54.46±10.29	53.25±6.72	-1.20±1.49$^{\#}$	0.419	-4.16; 1.75	7.84	<0.001	0.20
	EG2	55.16±7.48	47.40±7.68	-7.76±1.46*,**	<0.001	-10.65; -4.86			

	EG3	55.54±6.17	50.83±9.58	-4.73±1.52*	0.002	-7.76;-1.71		
	CG	55.76±11.32	57.20±8.51	1.44±1.46#,##	0.327	-1.45; 4.33		
RPP	EG1	11379.67±1442.92	10005.00±1365.80	-1374.66±251.81#,##	<0.001	-1874.71; -874.61	2.88	<0.001	0.42
	EG2	11254.00±1735.96	8507.64±1309.88	-2746.36±246.72*,**,##	<0.001	-3236.30; -2256.41		
	EG3	11545.13±1554.06	9528.30±1474.82	-2016.82±257.23*,**,#	<0.001	-2527.63; -1506.01		
	CG	11827.56±1474.97	11875.68±1132.23	48.12±246.72##	0.846	-441.82; 538.06		
RHR	EG1	79.04±11.20	73.54±9.51	-5.50±1.64*	0.001	-8.77; -2.23	7.02	<0.001	0.18
	EG2	78.40±11.05	69.72±8.49	-8.68±1.61*	<0.001	-11.88; -5.47		
	EG3	80.17±8.95	73.57±9.38	-6.60±1.68*	<0.001	-9.94; -3.26		
	CG	80.00±8.23	81.28±8.06	1.28±1.61**,#,##	0.430	-1.92; 4.48		
Weight (Kg)	EG1	91.45±16.59	91.32±16.45	-0.20±0.16	0.212	-0.53; 0.12	0.73	0.531	0.24
	EG2	78.11±14.18	77.75±13.89	-0.17±0.16	0.282	-0.49; 0.14		
	EG3	87.88±16.01	86.98±16.62	-0.40±0.16	0.019	-0.74; -0.68		
	CG	88.94±15.94	88.86±16.28	-0.04±0.16	0.806	-0.36; 0.28		
LBM (Kg)	EG1	30.28±6.34	30.77±6.31	-0.12±0.38*	0.756	-0.89; 0.64	0.76	0.514	0.24
	EG2	28.98±6.73	29.56±6.77	-0.35±0.37*	0.351	-1.11; 0.39		
	GE3	29.93±5.77	30.38±6.21	-0.89±0.39*	0.026	-1.68; -0.11		
	CG	30.56±5.98	30.38±5.92	-0.08±0.37**,#,##	0.825	-0.83; 0.67		
BFP (%)	EG1	39.70±8.09	38.73±8.20	-0.96±0.33	0.004	-1.62; -0.30	3.78	0.013	0.11
	EG2	32.62±10.27	31.55±9.75	-1.07±0.32	0.001	-1.71; -0.42		

	EG3	38.00±9.08	36.83±9.15	-1.17±0.33*	0.001	-1.84; -0.49			
	CG	37.69±8.44	37.89±8.70	0.19±0.32##	0.547	-0.44; 0.84			
BMI (Kg/m²)	EG1	32.61±5.14	32.40±5.11	-0.90±0.39	0.024	-1.68; -0.12	3.23	0.026	0.09
	EG2	27.43±4.87	27.25±4.56	-1.09±0.38	0.006	-1.85; -0.32			
	EG3	31.85±5.59	31.44±5.56	-1.46±0.40	<0.001	-2.26, -0.66			
	EG	31.90±4.99	31.86±5.09	0.18±0.38	0.628	-0.57; 0.95			
VF (cm²)	EG1	183.60±59.58	178.39±59.24	-5.21±2.12	0.016	-9.42; -0.99	3.32	0.023	0.09
	EG2	125.19±58.83	119.74±54.32	-5.44±2.07	0.010	-9.57; -1.31			
	EG3	165.07±56.86	156.66±56.29	-8.41±2.16*	<0.001	-12.71; -4.10			
	CG	165.25±54.58	166.10±55.82	0.84±2.07##	0.684	-3.28; 4.97			
Waist circumference (cm)	EG1	110.08±13.26	106.83±15.27	-3.25±0.88*,#	<0.001	-5.00; -1.49	12.66	<0.001	0.29
	EG2	98.76±10.54	92.16±10.58	-6.60±0.86*,**	<0.001	-8.32; -4.87			
	EG3	106.60±14.32	102.26±16.12	-4.34±0.90*	<0.001	-6.14; -2.55			
	CG	105.80±12.33	106.52±12.64	0.72±0.86**,#,##	0.409	-1.00; 2.44			

Note. SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MAP: Mean Blood Pressure; PP: Pulse Pressure: RPP: Rate Pressure Product; RHR: Resting Heart Rate; BMI: Body Mass Index; LBM: Lean Body Mass; BFP: Body Fat Percentage; VF: Visceral Fat; *Significantly different from corresponding CG value at the $p < 0.05$ level; **Significantly different from corresponding EG1 value at the $p < 0.05$ level; # Significantly different from corresponding EG2 value at the $p < 0.05$ level; ## Significantly different from corresponding EG3 value at the $p < 0.05$ level.

Table 3

Effect of multicomponent training and cardiovascular training on metabolic biomarket, and physical fitness

Outcome	Group	Pre-test (M±ED)	Post-test (M±ED)	No Adjusted			Group * time interaction		
				Difference post-pre (M±ED)	p	95% CI (Mpost-Mpre)	F	Sig	ES
CT (mg/dl)	EG1	192.25±40.54	185.04±23.10	-7.20±5.43*	0.18	-18.00; 3.58	7.34	<0.001	0.19
	EG2	199.72±30.11	192.08±29.20	-7.64±5.32*	0.15	-18.21; 2.93			
	EG3	195.73±38.36	177.16±35.48	-18.47±5.54*	0.001	-29.50; -7.45			
	CG	191.76±28.50	208.00±29.89	16.24±5.32**,#,##	0.003	5.66; 26.81			
HDL (mg/dl)	EG1	48.21±7.15	50.00±10.37	1.79±1.00	0.078	-0.20; 3.79	0.89	0.447	0.02
	EG2	54.44±9.92	55.32±11.29	0.88±0.98	0.375	-1.07; 2.83			
	EG3	48.17±11.63	49.17±12.30	1.00±1.02	0.333	-1.04; 3.04			
	CG	48.76±11.09	48.48±12.48	-0.28±0.98	0.777	-2.23; 1.67			
LDL (mg/dl)	EG1	118.27±36.36	110.45±21.58	-7.82±4.71*	0.100	-17.18; 1.53	6.65	<0.001	0.17
	EG2	120.61±24.77	114.14±24.54	-6.47±4.61*	0.164	-15.64; 2.70			
	EG3	118.15±36.26	105.30±32.60	-12.85±4.81*	0.009	-22.41; -3.29			
	CG	116.82±23.25	131.34±31.29	14.52±4.61**,#,##	0.002	5.34; 23.69			

TG (mg/dl)	EG1	126.08±52.16	121.91±36.94	-4.16±7.42	0.576	-18.91; 10.58	3.01	0.034	0.09
	EG2	122.32±59.16	113.72±43.21	-8.60±7.27	0.240	-23.05; 5.85			
	EG3	137.21±55.82	121.43±65.24	-15.78±7.58*	0.040	-30.84; -0.71			
	CG	133.44±64.33	147.96±79.97	14.52±7.27##	0.049	0.70; 28.97			
Glucose (mg/dl)	EG1	107.33±13.49	99.91±14.06	-7.41±1.60*	<0.001	-10.60; -4.22	11.73	<0.001	0.27
	EG2	98.16±14.69	91.36±10.77	-6.80±1.57*	<0.001	-9.92; -3.67			
	EG3	97.60±13.05	87.65±13.14	-9.95±1.64*	<0.001	-13.21; -6.69			
	CG	97.24±22.48	99.80±19.94	2.56±1.57**,#,##	0.107	-0.56; 5.68			
Handgrip RA	EG1	32.85±7.61	35.56±10.23	2.70±0.59*	<0.001	1.53; 3.88	7.91	<0.001	0.20
	EG2	31.18±9.80	33.24±11.18	2.06±0.57	0.001	0.91; 3.20			
	EG3	31.80±7.79	35.45±8.26	3.65±0.60*	0.80	2.45; 4.84			
	CG	31.42±8.73	31.56±8.81	0.14±0.57**,##	<0.001	-1.00;1.28			
1RM (Kg UB)	EG1	51.33±21.18	59.87±24.99	8.54±1.58*,#	<0.001	5.40; 11.68	41.34	<0.001	0.57
	EG2	46.24±23.68	65.12±30.34	18.88±1.54*,**,##	<0.001	15.80; 21.95			
	EG3	51.09±20.52	62.78±26.91	11.69±1.61*,#	<0.001	8.48; 14.90			
	CG	54.24±24.26	52.20±23.20	-2.04±1.54**,#,##	0.191	-5.11; 1.03			
MPV (m/s 50%)	EG1	0.97±0.02	1.08±0.07	0.10±0.01*,#	<0.001	0.08; 0.13	78.17	<0.001	0.71
	EG2	0.96±0.03	1.20±0.06	0.23±0.01*,**,##	<0.001	0.20; 0.26			
	EG3	0.96±0.03	1.10±0.06	0.13±0.01*,#	<0.001	0.10; 0.16			
	CG	0.97±0.02	0.92±0.04	-0.05±0.01**,#,##	<0.001	-0.07; -0.02			

1RM (Kg LB)	EG1	70.75±34.09	87.96±38.71	17.20±1.92*,#	<0.001	13.38; 21.03	49.49	<0.001	0.61
	EG2	73.08±35.11	98.32±41.42	25.24±1.88*,**	<0.001	21.49; 28.98			
	EG3	79.26±32.24	97.65±37.24	18.39±1.96*	<0.001	14.48; 22.29			
	CG	79.92±32.17	76.44±30.72	-3.48±1.88**,#,##	0.068	-7.22; 0.26			
MPV (m/s 60%)	EG1	0.99±0.02	1.15±0.08	0.16±0.01*,#	<0.001	0.13; 0.19	76.50	<0.001	0.71
	EG2	0.99±0.02	1.21±0.05	0.22±0.01*,**	<0.001	0.19; 0.25			
	EG3	0.98±0.02	1.16±0.06	0.17±0.01*	<0.001	0.14; 0.20			
	CG	0.99±0.02	0.95±0.05	-0.03±0.01**,#,##	0.006	-0.06; -0.01			
VO2p (ml/kg/min)	EG1	22.01±4.34	26.71±5.38	4.69±0.34*	<0.001	4.00; 5.38	57.55	<0.001	0.65
	EG2	25.08±3.82	30.86±4.40	5.78±0.33*,##	<0.001	5.10; 6.45			
	EG3	21.13±3.64	24.56±4.56	3.43±0.35*,#	<0.001	2.73, 4.13			
	CG	21.61±3.58	21.43±3.57	-0.18±0.33**,#,##	0.588	-0.85; 0.49			

Note. CT: Total Cholesterol; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; TG: Triglycerides; RA: right arm; LA: left arm; 1RM: Maximum Repetition; UL: Upper Limb; LL: Lower Limb; MPV: mean propulsive velocity; VO2p: Peak oxygen consumption; *Significantly different from corresponding CG value at the $p < 0.05$ level; **Significantly different from corresponding EG1 value at the $p < 0.05$ level; # Significantly different from corresponding EG2 value at the $p < 0.05$ level; ## Significantly different from corresponding EG3 value at the $p < 0.05$ level.

On the one hand, EG1, EG2, and EG3 showed significant improvements in SBP, DBP, MAP, RHrest, lean mass, waist circumference, TC, LDL, glucose, handgrip strength, 1RM upper body, upper limb MPV (m/s 50 %), 1RM lower body, lower limb MPV (m/s 60 %), and VO_2peak, with these changes being significantly greater than those of the CG. On the other hand, EG2 obtained greater changes in SBP, DBP, MAP, PP, RPP, waist circumference, 1RM upper body, upper limb MPV (m/s 50 %), 1RM lower body, and lower limb MPV (m/s 60 %) than EG1.

EG2 also showed further improvements in SBP, MAP, RPP, 1RM upper limb, upper limb MPV (m/s 50 %), and VO_2peak than EG3. Finally, the EG3 achieved major improvements in SBP, MAP, and RPP than EG1. Furthermore, it was the only intervention group that significantly reduced BFP (body fat percentage) with respect to the CG.

Finally, the EG3 achieved major improvements in SBP, MAP, and RPP than EG1. Furthermore, it was the only intervention group that significantly reduced BFP (body fat percentage) with respect to the CG.

5.16. DISCUSSION

The aim of the present study was to compare the effects of different individualized training programs, i.e., MICT, strength training combined with MITC, and strength training combined with HIIT, in adults with high blood pressure. The results showed that EG1, EG2, and EG3 significantly improved blood pressure levels, while the CG showed no change. One of the main findings of this research was that both groups with combined training showed greater improvements in these variables, with strength training combined with MICT showing the greatest benefits. It can be observed that the reductions in blood pressure levels obtained in this study were significantly greater than the results obtained in previous work with this same modality, despite the fact that the frequency of training was lower (López-Ruiz et al., 2023). These improvements could be linked to the rigorousness with which the intensity and volume of strength training was quantified, which provided the same training for all participants and a similar degree of exertion (Badillo, 2017; Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2022; Sánchez-Medina &

González-Badillo, 2011). The greater changes in the combined training groups could be attributed to an improvement in endothelial function induced by strength training. Endothelial dysfunction is associated with several cardiovascular risk factors, including hypertension. The endothelium plays an important role in vascular contractile modulation that is largely dependent on the bioavailability of nitric oxide (NO) (Gamboa et al., 2007; Node et al., 1997; Vallance et al., 1989). When the endothelium is damaged, it neutralizes NO production and stimulates the production of vasoconstrictive substances, leading to an increase in blood pressure (Brandes, 2014; Schulz et al., 2011). Strength training can stimulate NO production by increasing vascular AMPK/PPARδ and suppressing endoplasmic reticulum stress, thereby improving endothelial function (Boeno et al., 2020; Pedersen & Febbraio, 2012; Silva et al., 2021; Tian & Meng, 2019). Furthermore, although the two combined training groups had the same dose of strength training, the group that performed MICT showed greater improvements than the group that performed HIIT. This may be because aerobic exercise, performed over a prolonged period of time and at a moderate intensity, has been widely shown to have beneficial effects on endothelial function (Tao et al., 2023; You et al., 2021).

In terms of body composition variables, lean mass and waist circumference, the intervention groups showed significant improvements, while the CG showed no change. Physical exercise induces changes in body composition because during muscle contraction, hundreds of exerkines with autocrine, paracrine or endocrine effects are released into the bloodstream, with major health benefits (Di Raimondo et al., 2016; Pedersen & Saltin, 2015; Severinsen & Pedersen, 2020). Training can increase muscle mass and reduce fat percentage (Pedersen & Febbraio, 2012; Severinsen & Pedersen, 2020), as the secretion of some of these exerkines promotes muscle hypertrophy and myogenesis, lipolysis, and fatty acid oxidation, and induces the browning of white adipose tissue (Atakan et al., 2021; Pedersen, 2006; Pedersen & Febbraio, 2012; Severinsen & Pedersen, 2020). Likewise, the participants in the strength training groups showed the most improvement in these variables, with the combined MICT group again showing the most improvement. These results can be attributed to strength training, which promotes visceral fat loss by promoting metabolic adaptations in the abdominal subcutaneous adipose tissue, with a significant increase in lipolysis in this area, both during and after training (Khalafi et al., 2021; Severinsen & Pedersen, 2020; Wewege et al., 2022).

With regard to improvements in body composition, it is known that muscle is an important modifiable risk factor for the development of cardiovascular disease, also for cardiovascular disease mortality and for all-cause mortality; lean mass appears to have a protective effect against cardiovascular and metabolic disease (Carbone et al., 2020). On the other hand, recent studies have compared improvements in body composition with MICT vs HIIT training, showing that the changes brought about by both types of training are similar and even favor MICT in reducing body fat (Andreato et al., 2019; Keating et al., 2017; Wewege et al., 2017). In line with these changes, it can be observed that participants in the intervention groups also significantly reduced their total cholesterol, LDL and glucose values, with these reductions being significantly different from the CG, which did not change. These improvements could be brought about by the release of IL-6 during exercise, among other exerkines, as its signaling within muscle leads to an increase in basal glucose uptake and translocation of its transporter GLUT-4 (Pedersen & Febbraio, 2008, 2012; Severinsen & Pedersen, 2020), in addition to increasing intramyocellular or whole-body fatty acid oxidation through activation of AMPK (Pedersen & Febbraio, 2008, 2012; Severinsen & Pedersen, 2020).

In relation to physical fitness, the results showed significant improvements in all three training groups in both strength and cardiorespiratory fitness as compared to the CG. Regarding the strength gains of the three intervention groups, it is known that the practice of exercise, regardless of the modality performed, is capable of provoking structural (peripheral) and neural (central) physiological adaptations, as muscular action is necessary to overcome a load (Badillo & Serna, 2002; González-Badillo et al., 2022). The central adaptations of these groups were determined by the type of activity performed, the intensity of the work, and the duration of the action (Badillo & Serna, 2002). The combined strength training group with MICT showed greater improvements in manual pressure strength and maximal upper and lower limb strength than the continuous moderate-intensity group. These results may be a response to strength training, which achieves greater neural adaptations through increased recruitment and synchronization of motor units and stimulus frequency, as previously demonstrated in the literature (Del Vecchio et al., 2019; Enoka, 1997; Sale, 1988). These adaptations of the central nervous system as a whole contribute to gains and improvements in maximal strength. In terms of aerobic endurance, the results revealed significant changes in

the function of the cardiovascular and respiratory systems, with an improvement observed in maximal oxygen consumption and an increase in stroke volume and cardiac output. Exercise can lead to important adaptations in skeletal muscle, such as increased mitochondrial biogenesis and capillary density, with these responses to exercise reflected in an improved ability to transport and use oxygen to generate energy (Akimoto et al., 2005; Booth et al., 2015; Jung & Kim, 2014). Many studies support the important role of PGC-1α (peroxisome proliferator-activated receptor gamma 1α coactivator) in these muscle adaptations induced by aerobic endurance exercise, including its possible role in the complex regulation of mitochondrial quality (Baar et al., 2002; Halling & Pilegaard, 2020; Jung & Kim, 2014). Despite the controversy that combined training may interfere with the adaptations induced by the different metabolic pathways AMPK and m-TOR, activated by aerobic and strength training respectively, in the present study, it can be observed that EG2, strength training combined with MICT, obtained greater improvements in VO_2peak than EG1, which performed a single modality of continuous moderate-intensity training, showing the compatibility of the two modalities in the same session and showing a similarity with previous studies (Khalafi et al., 2022; Pito et al., 2022). These results can be justified by the large adaptive reserve that sedentary subjects have at the start of any exercise program. Previous studies have shown that sedentary subjects who begin a combined strength and endurance training program achieve a positive and additive response to the two exercise modalities, favoring a generic adaptation in the absence of a true specificity of the training effect (Coffey & Hawley, 2017). Another important factor to consider is the low degree of fatigue in strength training, which could explain the possible interference of this training modality, thus achieving a greater maintenance of the MHC IIX fibers (Pareja-Blanco, Rodríguez-Rosell, et al., 2017).

This study has some limitations that should be taken into account for future research, such as the total intervention time. It is possible that longer periods of time training will lead to more significant results in some of the variables. Another point to consider is an intervention group with only strength training that could have been compared with the other modalities, and the effects on blood pressure as compared to the other modalities could have been known more precisely. Finally, another limitation was the daily intake of the participants, as the diet could have been controlled by making a daily dietary record.

Despite these limitations, this would be the first study in a hypertensive population comparing different strength training modalities, based on an individual assessment of the load-velocity relationship, combined with MICT and HIIT, versus continuous moderate-high intensity training. Another contribution and strength of this study is the precision with which the effort was dosed through the speed of execution, which allowed the workload to be individualized for each participant, ensuring that the stimulus programmed for strength training was truly the one applied and executed by each of them. More importantly, this quantification of load allowed all hypertensive participants to perform the same training and reach a similar degree of fatigue.

5.17. CONCLUSION

The results of the present study indicate that the implementation of a strength training program, based on an individual assessment of the load-velocity relationship, combined with MICT in the same session, 2 days per week for 12 weeks, produces significant improvements in blood and metabolic biomarkers, body composition, and physical condition, in adults with hypertension, with these adaptations being superior to those produced by MICT and strength training combined with HIIT, which also show improvements, but to a lesser extent.

Vd – ESTUDIO 4:
DISEÑO DE PROGRAMAS DE ENTRENAMIENTO COMBINADO INDIVIDUALIZADO PARA ADULTOS CON HIPERTENSIÓN ARTERIAL

Vd - ESTUDIO 4: Diseño de Programas de Entrenamiento Combinado Individualizado para Adultos con Hipertensión Arterial.

5.18. RESUMEN

Actualmente la enfermedad cardiovascular es la causa principal de muerte en el mundo. Entre los factores de riesgo desencadenantes de muerte cardiovascular a nivel mundial se encuentra la hipertensión arterial. En consecuencia, son muchos los planes estratégicos para abordar y mejorar los niveles de presión arterial con el objetivo de frenarla la alta incidencia de mortalidad anual, encontrándose entre estas estrategias los programas de ejercicio físico. Por ello, el objetivo de este trabajo es proporcionar a los profesionales de la salud una guía para poder diseñar correctamente un programa de entrenamiento combinado individualizado efectivo, de fuerza y resistencia aeróbica, con la finalidad de mejorar la salud cardiometabólica de esta población. En el presente trabajo se abordan las actuales recomendaciones sobre prescripción de ejercicio físico en personas con hipertensión, y se aportan consideraciones generales a tener en cuenta para la práctica del mismo. Además, se hace referencia al efecto de los fármacos durante el ejercicio físico y cómo tenerlo presente durante su realización, se describen cuales son las adaptaciones agudas al ejercicio y las recomendaciones para el entrenamiento combinado de resistencia y fuerza en esta población. Por último, se propone un programa de entrenamiento combinado individualizado para personas con hipertensión de 12 semanas de duración con una frecuencia de entrenamiento de 2 días/semana. Para el entrenamiento de fuerza la intensidad será baja-moderada y el volumen será bajo, ambas variables individualizadas a través de la velocidad de ejecución; se relizarán 2 ejercicios, 3 series/ejercicio y en progresión horizontal. Para el entrenamiento de resistencia aeróbica la intensidad será baja progresando a moderada, del 55% al 70% de la FCresv incrementando cada 4 semanas, esta variable será individualizada mediante un test clínico en cicloergómetro; el volumen será de 20 min/sesión en bicicleta estática.

Palabras Clave: Presión arterial alta, ejercicio, entrenamiento concurrente, fuerza, resistencia

5.19. INTRODUCCIÓN

Los últimos estudios epidemiológicos posicionan a la enfermedad cardiovascular como primera causa de muerte en el mundo, con la cardiopatía isquémica en primer lugar, seguida del accidente cerebrovascular. Estos estudios también apuntan que la hipertensión arterial sigue siendo el principal factor de riesgo modificable de muerte cardiovascular a nivel mundial, responsable de más de 10 millones de muertes al año (Mensah et al., 2023; Unger et al., 2020; Vaduganathan et al., 2022). Una de las metas de la Organización Mundial de la Salud (OMS) para 2025, en relación con las enfermedades no transmisibles, es reducir la prevalencia de la hipertensión arterial en un 25% (tomando como referencia los datos de 2010) (OMS, 2023), pero a día de hoy las cifras de incidencia y mortalidad por dicha enfermedad siguen aumentando.

La hipertensión arterial se considera un trastorno crónico y prácticamente asintomático con una etiología multifactorial sin causa concreta. Se puede diferenciar entre hipertensión primaria y secundaria, la más frecuente es la primaria, que corresponde al 90-95% aproximadamente de los casos; la hipertensión secundaria, mucho menos común, suele presentarse en un 5-10% de los pacientes hipertensos (Rimoldi et al., 2014; Unger et al., 2020). La hipertendión primaria es muy heterogénea y presenta una serie de factores de riesgo intrínsecos (no modificables) por su origen biológico y otros factores extrínsecos (modificables) por su naturaleza ambiental asociados al estilo de vida (Gorostidi et al., 2022). Más del 50% de las personas con hipertensión arterial presentan otros factores de riesgo adicionales como sobrepeso-obesidad, dislipemia, resistencia a la insulina o diabetes tipo II; así como unos hábitos de vida poco saludables, entre los que se encuentra el sedentarismo o una mala alimentación (Menéndez et al., 2016; Unger et al., 2020). Con respecto a la hipertensión secundaria, su etiología se puede clasificar en frecuentes e infrecuentes. Entre las causas frecuentes figuran la enfermedad renal parenquimatosa, la enfermedad renovascular, el hiperaldosteronismo primario, el síndrome de apnea-hipopnea del sueño y la hipertensión inducida por fármacos (Unger et al., 2020; Whelton et al., 2018b).

Las últimas guías europeas de cardiología e hipertensión consideran hablar de hipertensión arterial cuando en consulta los niveles de presión arterial sistólica son iguales o superiores a 140 mmHg y/o los niveles de presión arterial diastólica

son iguales o superiores a 90 mmHg, aunque los valores de corte para definir hipertensión arterial en el hogar o con dispositivos de registro de 24 horas son mostrar una tensión arterial sistólica igual o superior a 135 mmHg y/o una presión arterial diastólica igual o superior a 85 mmHg (Mancia et al., 2023).

En la actualidad existe suficiente evidencia para justificar que el ejercicio físico actúa como una intervención capaz de prevenir y tratar numerosas enfermedades no trasmisibles, entre ellas se encuentran las enfermedades cardiometabólicas, inmunológicas, neurológicas o incluso enfermedades como el cáncer (Pedersen, 2006; Pedersen & Saltin, 2015). En esta línea de los beneficios para la mejora de la salud y la calidad de vida de las personas que se consiguen a través de las terapias no farmacológicas, se pueden encontrar grandes estudios epidemiológicos donde se ha mostrado una relación inversa entre la incidencia de hipertensión arterial y la práctica de ejercicio físico (Liu et al., 2017; Rijal et al., 2024). Las intervenciones no farmacológicas son claves para la prevención y tratamiento de este trastorno; estas intervenciones requieren cambios en los hábitos y conductas de la vida diaria, como abandonar el sedentarismo y comenzar con la práctica de ejercicio físico de forma habitual (Charchar et al., 2024; Pelliccia et al., 2020; Whelton et al., 2018b). En 1989, y por primera vez, la OMS y la Sociedad Internacional de Hipertensión Arterial incluyeron recomendaciones de ejercicio físico entre las medidas no farmacológicas destinadas a la disminución de los valores de la presión arterial (OMS, 1989).

En el ámbito clínico las guías de patología cardiovascular e hipertensión marcan las directrices sobre la prescripción de ejercicio físico a nivel mundial en este tipo de población. Estos documentos internacionales contemplan recomendaciones muy generales para la mejora de la salud cardiovascular (Mancia et al., 2023; Unger et al., 2020; Whelton et al., 2018b). El ejercicio de resistencia aeróbica ha sido una modalidad bien estudiada por la comunidad científica y se considera, hasta la fecha, el entrenamiento prioritario para sujetos con hipertensión, por ser la modalidad que mayores beneficios obtiene sobre los niveles de presión arterial, con reducciones de -4,9 a -12 mmHg en presión arterial sistólica y de -3,4 a -5,8 mmHg en presión arterial diastólica (Hanssen et al., 2021; Mancia et al., 2023; Pescatello et al., 2015). El trabajo de fuerza se recomienda como entrenamiento complementario al de resistencia, para que los pacientes se puedan

beneficiar de las mejoras que ofrece dicha modalidad, entre esas mejoras reducciones de -3,0 a -4,7 mmHg en presión arterial sistólica y de -3,2 a -3,8 mmHg en presión arterial diastólica (Hanssen et al., 2021; Mancia et al., 2023). El entrenamiento combinado de ambas modalidades, fuerza y resistencia, en la misma sesión de entrenamiento también ofrece grandes beneficios para la salud cardiometabólica, como ya se ha demostrado en estudios previos (Corso et al., 2016; López-Ruiz et al., 2023). Esta modalidad combinada es una buena herramienta para abordar la hipertensión arterial debido a las reducciones significativas que tiene sobre los niveles de presión arterial, de hasta -21,68 mmHg en los niveles de presión arterial sistólica y de hasta -13,92 mmHg en los de presión arterial diastólica, incluso, presenta mayores reducciones que el entrenamiento de resistencia por sí solo, de hasta -12,8 mmHg, -6,8 mmHg respectivamente.

5.20. PRESCRIPCIÓN DE EJERCCIO FÍSICO PARA LA MEJORA DE LA SALUD CARDIOMETABÓLICA EN SUJETOS ADULTOS CON HIPERTENSIÓN ARTERIAL

5.20.1. **Consideraciones generales para la práctica de ejercicio físico**

Antes de comenzar con un programa de entrenamiento es importante que el sujeto pase por un reconocimiento médico en el que se realizarán unas pruebas rutinarias recomendadas para sujetos con hipertensión arterial, con ello se podrá descartar un riesgo aumentado de ECV o comorbilidades relevantes y garantizar la seguridad para el desarrollo de los programas de entrenamiento. Las pruebas incluyen: analisis de sangre para medir la hemoglobina glucosilada (HbA1C), los electrolitos, la creatinina, la tasa de filtración glomerular y el perfil lipídico; analisis de orina para estimar la ratio albúmina:creatinina y comprobar la hematuria mediante una tira reactiva; examinar el fondo de ojo para detectar la presencia de retinopatía hipertensiva; y por último, un electrocardiograma de 12 derivaciones (McEvoy et al., 2024; NICE, 2023; Unger et al., 2020).

Las guías clínicas internacionales de cardiología e hipertensión recomiendan la práctica de ejercicio físico como tratamiento no farmacológico para la mejora y el control de la hipertensión arterial (Charchar et al., 2024; Rabi et al., 2020; Unger et al., 2020; Whelton et al., 2018b). Estas pautas recomiendan realizar

entrenamiento de resistencia de 150 a 300 min/semana (5-7 días/semana) con intensidad moderada y se puede alternar de 75 a 150 min/semana (2-3 días/semana) con intensidad vigorosa (Charchar et al., 2024; McEvoy et al., 2024; Pelliccia et al., 2020; Rabi et al., 2020). Algunos de estos documentos también recomiendan incorporar de 2 a 3 días por semana entrenamiento de fuerza, como complementario al de resistencia aeróbica, sin profundizar sobre su prescripción (Brook et al., 2013; Charchar et al., 2024; Hanssen et al., 2021; Whelton et al., 2018b).

Estos patrones de ejercicio deben ser integrados dentro de una sesión completa de entrenamiento que debe mantener siempre la misma estructura, sea cual sea el programa de ejercicio o disciplina deportiva que se vaya a realizar. La estructura de la sesión se compone de tres fases sólidas y sucesivas, la fase de preparación al entrenamiento o calentamiento, la fase principal y fase de recuperación post-entrenamiento o vuelta a la calma, que garantizan la salud y la mejora del rendimiento del sujeto (Bishop, 2003a, 2003b; Fradkin et al., 2010; McGowan et al., 2015).

Actualmente, las guías clínicas no hacen referencia a todas las fases de esta estructura, centrándose exclusivamente en la fase principal de la sesión (Arnett et al., 2019; Brook et al., 2013; Charchar et al., 2024; Mancia et al., 2023; Pelliccia et al., 2020; Rabi et al., 2020). Antes de comenzar con la fase principal, es necesario realizar una fase preparatoria especifica que aumente de forma gradual la frecuencia cardiaca (FC), la actividad pulmonar y el flujo sanguíneo para incrementar el aporte de oxígeno al organismo en general y a nivel muscular en paticular; que aumente la temperatura de la musculatura implicada mejorando la elasticidad muscular evitando distensiones, desgarros y roturas, así como la viscosidad sinovial para facilitar el deslizamiento de las articulaciones. Una vez terminada la fase principal, es necesario realizar una fase de recuperación post-entrenamiento para volver al estado de reposo de forma gradual. Es importante conocer que la medicación antihipertensiva puede provocar reducciones repentinas y excesivas de la presión arterial después del ejercicio, este periodo de vuelta a la calma debe ser prolongado y controlado (Bishop, 2003a, 2003b; Fradkin et al., 2010; McGowan et al., 2015; Pescatello, 2020; Safran et al., 1989; Taylor et al., 2019; Woods et al., 2007).

Estas directrices generales, en un primer momento, pueden servir de ayuda a los pacientes hipertensos para comenzar a moverse y llevar una vida más activa.

Sin embargo, la individualización es uno de los principios básicos del entrenamiento y seleccionar los ejercicios dependiendo de los objetivos y necesidades de cada sujeto, programar de manera precisa la carga de trabajo y utilizar la metodología más adecuada será muy importante para conseguir los mejores resultados (Fleck & Kraemer, 2014; Pescatello, 2020; San-Millán, 2023).

Otras recomendaciones a tener en cuenta en este tipo de población serán, por un lado, evitar la maniobra de Valsalva durante la ejecución técnica de los ejercicios de fuerza; prestar especial atención a los ejercicios de hemisferio superior y/o con los brazos por encima de la cabeza, por la respuesta hipertensiva que provocan; tener cuidado con los ejercicios estáticos y a llegar al fallo muscular, por la dificultad de controlar la maniobra de Valsalva, la respuesta hipertensiva o el riesgo de lesión (Nazir et al., 2024; Williams et al., 2007).

Por otro lado, la indumentaria también será importante para una práctica de ejercicio físico segura. Algunos medicamentos antihipertensivos, betabloqueantes o diuréticos, afectan la capacidad de regular la temperatura corporal durante el ejercicio, sobre todo en ambientes cálidos y/o húmedos, lo que puede provocar una hipoglucemia. El sujeto debe llevar prendas transpirables y cómodas para evitar la sudoración excesiva y lesiones en la piel. Respecto al calzado, será recomendable el uso de zapatillas deportivas. Se deben evitar prendas y fajas efecto sauna que puedan favorecer un sincope (Marcos-Pardo et al., 2021; Pescatello, 2020).

Por último, la hidratación es un factor relevante en este grupo de población tratados con betabloqueantes o diuréticos, antes, durante y después del entrenamiento, para evitar una posible deshidratación (Marcos-Pardo et al., 2021; Pescatello, 2020).

En base a todo lo expuesto, y con el objetivo de prevenir y tratar la hipertensión arterial, se debería desde el ámbito médico animar a los pacientes a buscar ayuda en los profesionales del ejercicio físico para realizar un correcto e individualizado programa de entrenamiento, así como asesoramiento y recomendaciones para el momento de la práctica.

5.21. FÁRMACOS ANTIHIPERTENSIVOS Y EJERCICIO FÍSICO

Lorem ipsum dolor sit amet consectetur adipiscing elit himenaeos, cursus laoreet sed ornare phasellus eget nunc magnis, a nec sociis Son muchos los medicamentos disponibles para tartar la hipertensión arterial y los posibles efectos secundarios de estos fármacos deben tenerse en cuenta a la hora de comenzar con un programa de ejercicio físico, dado que pueden afectar a las respuestas fisiológicas (Khalil & Zelster, 2020; Laurent, 2017; Pelliccia et al., 2020):

- Inhibidores de la enzima convertidora de angiotensina (IECA): pueden producir erupción cutánea, pérdida de sabor o tos seca y persistente, pero no afectan la capacidad de realizar ejercicio. No deben ser administrardo a mujeres en edad reproductiva debido a los posibles efectos adversos fetales/neonatales.
- Antagonistas del receptor de la angiotensina II (ARA-II): pueden provocar mareos ocasionales, pero no afectan la capacidad de realizar ejercicio. No deben ser administrardo a mujeres en edad reproductiva debido a los posibles efectos adversos fetales/neonatales.
- Bloqueadores de los canales de calcio o calcioantagonistas: son la mejor opción alternativa a los IECA y ARAII. Pueden provocar palpitacionesn, hinchazón de tobillos, cefaléas y mareos, pero no afectan la capacidad de realizar ejercicio.
- Betabloqueantes: pueden provocar insomnio, frialdad de manos y pies, asma y depresión. Estos fármacos afectan la capacidad de realizar ejercicio, puesto que reducen la frecuencia cardiaca y diminuyen la tolerancia al esfuerzo aumentando la sensación de fatica.
- Los diuréticos: pueden provocar fatiga, debilidad o calambres musculares, ataques de gota, irritabilidad, depression e incontinencia urineria. Estos fármacos si afecta la capacidad de realizar ejercicio, puesto que aumenta la diuresis y favorece la deshidratación.

Cuando un sujeto con hipertensión arterial comienza un programa de ejercicio físico y está bajo tratamiento antihipertensivo se debe tener en cuenta los posibles efectos del mismo: a) la respuesta hipotensiva post-ejercicio; b) la respuesta hipotensiva por cambios de posición, (hipotension ortostática); c) la respuesta hipotensiva como consecuencia de la temperatura (calor y humedad); y

d) la respuesta hipotensiva debido a la práctica de ejercicio físico de manera regular y mantenida en el tiempo; estas situaciones pueden hacer que el sujeto experimente mareos, aturdimiento, inestabilidad, nauseas y sensación de cansancio y/o fatiga (Khalil & Zelster, 2020; Laurent, 2017). Ante cualquier situación de hipotensión con sintomatología el sujeto debe ser derivado a su médico para que revise y ajuste el tratamiento si lo ve necesario. Se debe prestar especial atención a los sujetos tratados con betabloqueantes, dado que este fármaco disminuye la frecuencia cardiaca en el esfuerzo y si se atenúa demasiado también podría ocasionar mareos, inestabilidad y sensación de cansancio Y/o fatiga (Khalil & Zelster, 2020; Laurent, 2017; Mitchell et al., 2019). De todos los fármacos antihipertensivos, los betabloqueantes son los que más pueden afectar a la capacidad física para realizar ejercicio, ya que al disminuir el ritmo cardiaco durante la práctica será difícil controlar y ajustar correctamente la carga o estímulo de entrenamiento y conseguir la frecuencia cardiaca deseada, esto implica tener que buscar otra herramienta o método alternativo para controlar dicha variable (Adami et al., 2022; Mitchell et al., 2019). El control de la intensidad del ejercicio a través de la escala de esfuerzo percivido puede ser un método fiable y comúnmente utilido en los programas de rehabilitación cardica como complemento al monitoreo de la frecuencia cardiaca (Mitchell et al., 2019; Taylor et al., 2019). En relación esto, es importante entender que las ecuaciones para estimar la frecuencia cardiaca máxima (FCmáx), como la fórmula de Fox (FCmax = 220-edad) o la fórmula de Tanaka (FCmax = 208-(0,7*edad), estan basadas en sujetos sanos que no padecen hipertensión arterial, insuficiencia cardiaca o enfermedad coronaria y que no están en terapia con betabloqueantes, con lo cual, este tipo de ecuaciones no parecen ser muy validas para este tipo de población. Sin embargo, existen fórmulas para estimar la FCmáx que consideran la enfermedad cardiovascular tratada con betabloqueantes. Por ello, se propone la siguiente fórmula para la población que presenta este tipo de afección: 164 - 0,7 x edad, siendo una ecuación más precisa en este grupo de población (Brawner et al., 2004; Fernandes Silva et al., 2012; Taylor et al., 2019).

5.22. ADAPTACIÓN AGUDA DE LA PRESIÓN ARTERIAL AL EJERCICIO FÍSICO

La práctica de ejercicio físico induce una serie de respuestas fisiológicas en el organismo y entre ellas se encuentran los cambios en la dinámica de la presión arterial.

Al inicar la práctica de ejercicio físico se produce un aumento de la presión arterial como respuesta de la activación de la corteza motora cuyo objetivo es preparar al organismo. A continuación, los valores de la presión arterial pueden disminuir debido a la vasodilatación de las zonas activas, dependiendo del tamaño del área de las zonas implicadas. A medida que aumenta la intensidad del entrenamiento la presión arterial sistólica, generalmente, aumenta de manera lineal, por el contrario, la presión arterial diastólica aumenta menos, se mantiene relativamente estable o incluso experimenta una ligera bajada. Al terminar la práctica de ejercicio físico, se recupera paulatinamente los niveles de presión arterial en reposo, pudiendo tardar un tiempo en volver a los niveles previos al entrenamiento. Si la vuelta a la calma no se realiza de manera gradual, puede producirse una hipotensión post-ejercicio, principalmente en sujetos susceptibles o en condiciones climáticas desfavorables, provocando malestar, vertido o lipotimias (Halliwill, 2001; Halliwill et al., 2013; Seeley et al., 2021).

Estas oscilaciones transitorias de la presión arterial durante el ejercicio hacen que sea fundamental su monitorización y control antes, durante y después de la práctica para evitar algún evento cardiaco fatal e inesperado. Las variaciones extremas de estas respuestas pueden ser un valor pronostico significativo de posibles eventos adversos cardiovasculares (Nayor et al., 2023; Pesova et al., 2023). Un aspecto importante a destacar sobre estos cambios extremos es la falta de consenso sobre la definición de respuesta hipertensiva al ejercicio, pese a ello, valores de presión arterial sistólica por encima o igual a 210 mmHg para los hombres y 190 mmHg para las mujeres son los puntos de corte utilizados a nivel mundial para detener la práctica deportiva y considerar que existe una respuesta hipertensiva al ejercicio (Fletcher et al., 2013; Sabbahi et al., 2018).

5.23. ENTRENAMIENTO DE RESISTENCIA AERÓBICA INDIVIDUALIZADO EN HIPERTENSIÓN ARTERIAL

- La frecuencia es una variable que hace referencia al número de sesiones o unidades de entrenamiento realizadas en un periodo de tiempo, en el ámbito de la salud, normalmente, sería en la semana (Elvar & García-Orea, 2019). La frecuencia de entrenamiento mínima para este grupo de población será de 2-3 días por semana.
- La duración de la sesión será ≤60 minutos.
- La intensidad de entrenamiento prioritaria para mejorar la salud cardiometabólica será moderada, estará entre el 55%-70% del $VO^2máx$ o FCresv, lo que conoce como Zona 2 de entrenamiento (Gu et al., 2021; Riddell et al., 2017; San-Millán, 2023). Para programar la intensidad del entrenamiento de forma individualizada se recomienda estimar el volumen máximo de oxígeno ($VO^2máx$), la FCmáx, la frecuencia cardiaca de reserva (FCresv) o la percepción de esfuerzo subjetivo (RPE); siendo de preferencia el uso del $VO^2máx$ o la FCresv por su relación lineal 1/1 con el gasto energético ($VO^2máx$/ VO^2 de reserva) (Ferguson, 2014; Liguori & Medicine, 2020; Marqueta et al., 2016). El cálculo de estos parámetros puede valorarse de manera directa o indirecta. Uno de los protocolos más indicados para estimar del $VO^2máx$ en población hipertensa es por medio de una prueba de esfuerzo en cicloergómetro, por ser más preciso y fácil para medir la presión arterial durante el esfuerzo (Marqueta et al., 2016). Durante la prueba se debe monitorizar y registrar en todo momento la frecuencia cardiaca para conocer la FCmáx; simultáneamente se debe registrar la RPE (Borg, 1990); y además, se debe medir la potencia para conocer el umbral de potencia funcional (FTP), que ofrece una forma precisa y objetiva de medir la intensidad del entrenamiento (Allen et al., 2019). Como se ha comentado anteriormente, la FCmáx también se puede estimar a través de diferentes fómulas. La más utilizada en el ámbito de la salud son las ya comentadas fórmulas de Fox (Fox et al., 1971; Liguori & Medicine, 2020) o fórmula de Tanaka (Tanaka et al., 2001), pero el valor resultante no es preciso si no meramente orientativo, y para población sin patología. Se propone el uso de la siguiente fórmula para el cálculo de la FCmáx en población con

patología cardiaca (FCmáx = 64 - 0,7 x edad) (Brawner et al., 2004; Fernandes Silva et al., 2012; Taylor et al., 2019).

Por otro lado, la FCresv y su utilización para el calculo de la intensidad de entrenamiento será más preciso que el uso de la FCmáx y para su cálculo será necesario conocer la frecuencia cardiaca basal o reposo (FCbasal). La FCresv se calculará por medio de la fómula de Karvonen: FCresv = FCmáx - FCbasal. Una vez conocido estos datos se calculará el porcentaje prescrito de intensidad. Para ello se utilizará la fórmula de Karvonen (% de FC= (FCresv × % de intensidad) + FCbasal) (Karvonen et al., 1957).

- En relación con la escala RPE (Rating of Perceived Exertion), definida como la percepción subjetiva del esfuerzo, tensión y/o fatiga experimentada durante la práctica de ejercicio físico, es un indicador de intensidad fiable y comúnmente utilizado en los programas de rehabilitación cardiaca simultáneamente con el monitoreo de la frecuencia cardiaca (Mitchell et al., 2019; Taylor et al., 2019). Esta escala valora numéricamente y de forma gradual del 0 al 10, donde 0 es reposo total y 10 esfuerzo máximo (Borg, 1982).
- Las zonas e intensidades de entrenamiento, desde ergometrías máximas, quedan reflejadas en la tabla 1 (Hansen et al., 2021; Pelliccia et al., 2020).

Tabla 1

Zonas e Intensidades de Entrenamiento de Resistencia

Zona	Intensidad	VO²máx (%)	FCmáx (%)	FCresv (%)
1	Baja	<40	<55	<40
2	Moderada	40-69	55-74	40-69
3-4	Alta	70-85	75-90	70-85
5	Muy Alta	>85	>90	>85

Nota. Esta tabla muestra la equivalencia de las zonas de entrenamiento con la intensidad de entrenamiento, el volumen máximo de oxígeno (VO²máx), la frecuencia cardiaca máxima (FCmáx) y la frecuencia cardiaca de reserva (FCresv) (Pelliccia et al., 2020).

- El volumen de entrenamiento mínimo para este tipo de población será de 150 a 300 minutos/semana (5-7 días/semana) si el ejercicio se realiza con intensidad moderada (zona 2). Se puede alternar de 75 a 150 minutos/semana (2-3 días/semana) si la intensidad es vigorosa (zona 3) (Bull et al., 2020; McEvoy et al., 2024).
- El tipo de actividad a realizar debe implicar grandes grupos musculares, movimientos cíclicos y mantenidos durante un medio-largo periodo de tiempo como pedalear, correr, remar, nadar etc.

5.24. ENTRENAMIENTO DE FUERZA INDIVIDUALIZADO EN HIPERTENSIÓN ARTERIAL

- La frecuencia mínima de entrenamiento para este grupo de población será de 2-3 días por semana no consecutivos.
- La duración de la sesión ≤60 minutos.
- Incluir ejercicios poliarticulares que impliquen grandes grupos musculares que simulen actividades de la vida diaria (sentadillas, remos, press banca, etc).

- El número de ejercicios por sesión se deben progresar de 6 hasta 8-10 ejercicios (López-Ruiz et al., 2023; Pescatello, 2020; Whelton et al., 2018b).
- La intensidad en el entrenamiento de fuerza será la variable más determinante para configurar el grado de esfuerzo que exige la ejecución de un ejercicio en cada repetición, que debe ser bajo-moderado para este grupo de población (Badillo & Serna, 2002; Elvar & García-Orea, 2019). La cuantificación de la carga de entrenamiento se hará a través de la velocidad de ejecución mediante un test de cargas progresivas para estimar la 1RM, de manera segura y precisa, y determinar la intensidad relativa de trabajo, pero la intensidad, por si sola, no es suficiente para definir el estímulo de entrenamiento y debe ir unida especialmente a otra de las variables de la programación, a el volumen (Badillo, 2017; Badillo & Serna, 2002).
- El volumen se debe concretar mediante un test de porcentaje de la perdida de velocidad intra-serie con respecto a la 1ª repetición. La magnitud de perdida de velocidad debe ser baja-moderada, entre un 10%-20%, ya que porcentajes más altos de perdida de velocidad no se asocian con mayores beneficios y pueden suponer una reducción del rendimiento físico (Badillo & Serna, 2002; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Rodríguez-Rosell et al., 2021).

A continuación, se realiza una propuesta de protocolo para prescribir la intensidad en sujetos con hipertensión arterial. La intensidad se determinará a través de un test de cargas progresivas para estimar la 1RM y establecer una intensidad baja-moderada de trabajo, entre el 50-65% de 1RM para este tipo de población (Alves et al., 2022; Pescatello, 2020). Las recomendaciones actuales de intensidad de trabajo en el entrenamiento de fuerza en hipertensión, según el Colegio Americano de Medicina del Deporte (ACSM), son las siguientes: intensidad baja, entre el 40%-50% de 1RM, para sujetos sedentarios o con debilidad muscular; intensidad moderada, entre el 60%-70% de 1RM, para sujetos principiantes o intermedios; intensidad alta, un 80% de 1RM, para sujetos avanzados y experimentados en el entrenamiento (Alves et al., 2022; Pescatello, 2020; Pescatello et al., 2015).El volumen de entrenamiento, o número de repeticiones por serie, se concretará a través de un test de perdida de velocidad intraserie para cada sujeto. La magnitud de perdida de velocidad

(%PV) debe ser baja-moderada, entre un 10-15% (Badillo, 2017; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Pareja-Blanco, et al., 2020; Sánchez-Medina & González-Badillo, 2011).

- El carácter de esfuerzo (CE) debe ser medio-bajo. Se entiende por CE la relación entre las repeticiones realizadas en cada serie con respecto a las repeticiones que se podrían realizar si se llegara al fallo muscular (Badillo & Serna, 2002), como se puede ver en la tabla 2. No confundir el CE con la percepción subjetiva de esfuerzo.

Tabla 2

Caracter de Esfuerzo

CE	%PV en la serie	Repeticiones realizadas en la serie
Bajo	5-10%	Menos de la mitad de las posibles
Medio	15-30%	La mitad de las posibles
Alto	>30%	Alguna más de la mitad de las posibles
Máximo	>50%	Máximo o casi máximo número de las posibles

Nota. Esta tabla muestra la relación entre el caráter de esfuerzo (CE), el porcentaje de perdida de velocidad (%PV) intra-serie respecto a la 1ª repetición y las repeticiones realizadas por serie con respecto a las máximas que realmente se podrían realizer (Badillo & Serna, 2002).

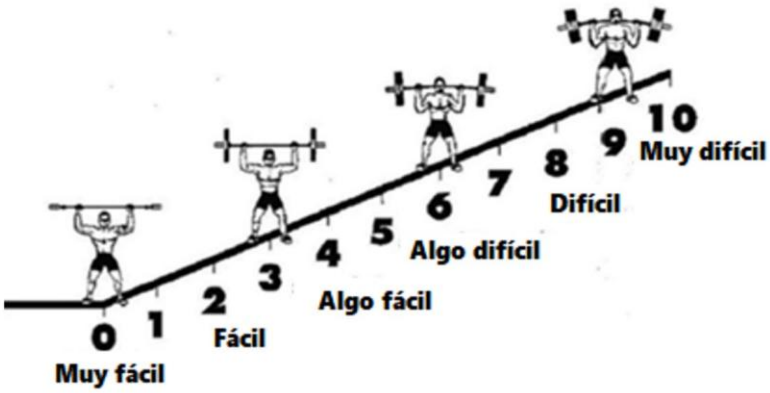
- El número de series por ejercicio pueden ser de 2 a 4, según el punto de partida y la evolución del sujeto.
- El tiempo de recuperación entre series de entrenamiento será de 3 a 5 minutos

- El tiempo de recuperación entre sesiones de entrenamiento será de 48 a 72 horas.

Respecto a la programación del entrenamieto, aunque cada vez se dispone de más recursos y dispositivos tecnológicos, que sin duda han permitido programar de forma más precisa la intensidad y el volumen del entrenamiento y conseguido evolucionar en la dosificación del esfuerzo, no se debe menospreciar otras herramientas o indicadores más simples y que son fácilmente accesibles para este mismo fin. Una de estas herramientas es la escala OMNI-RES, la cual se presenta como descriptores visuales donde el sujeto identifica su propia percepción de esfuerzo o fatiga sobre una escala numéricamente gradual del 0 al 10, como se muestra en la figura 1, donde 0 es muy fácil y el 10 es muy dificil, durante o inmediatamente después del ejercicio (Robertson et al., 2003).

Figura 1

Escala OMNI-RES para fuerza



Nota. Esta escala representa la propia percepción de esfuerzo o fatiga del sujeto sobre una progresión numéricamente del 0 (muy fácil) al 10 (muy difícil) (Robertson et al., 2003).

5.25. ENTRENAMIENTO COMBINADO INDIVIDUALIZADO EN HIPERTENSIÓN ARTERIAL

El ensayo clínico Corazón y Salud se centra en los programas de entrenamiento combinado, entendido este como aquel que en la misma sesión de entrenamiento combina unidades de entrenamiento diferentes, el trabajo de fuerza y el de resistencia aeróbica. El entrenamiento combinado ha mostrado ser eficaz en la reducción de los niveles de presión arterial y en la mejora de la salud cardiometabólica en sujetos con hipertensión arterial (Herrod et al., 2018; López-Ruiz et al., 2023). Diferentes ensayos controlados han mostrado reducciones significativas en los niveles de PAS y PAD con intervenciones de programas de entrenamiento combinado (Dos Santos et al., 2014; Lima et al., 2017; Masroor et al., 2018; Sousa et al., 2013). Además, se pueden encontrar revisiones sistemáticas y metaanálisis cuyos resultados también han mostrado que intervenciones con entrenamiento combinado consiguieron reducir significativamente los niveles de PAS y PAD (Corso et al., 2016; López-Ruiz et al., 2023; Pescatello et al., 2019).

La intención del presente proyecto es servir de guía a los profesionales de la salud para poder diseñar los programas de entrenamiento combinado de manera individualizada para cada sujeto con una dosis mínima, pero efectiva, de ejercicio. Estas intervenciones van dirigidas a sujetos adultos con hipertensión arterial, sedentarios, que no sufran problemas osteoarticulares o musculoesqueléticos (osteoartritis, fractura reciente, tendinitis o uso de prótesis), enfermedad aguda o crónica (cardiopatías, enfermedad coronaria inestable, insuficiencia cardíaca, insuficiencia renal, hipertensión pulmonar grave o diabetes no controlada), problemas neurológicos, dificultades cognitivas, obesidad mórbida o embarazadas.

5.26. PROGRAMA DE ENTRENAMIENTO CORAZÓN Y SALUD

A continuación, se muestra un diseño de programa de entrenamiento combinado individualizado de fuerza y resistencia aeróbica teniendo en cuenta las pautas de ejercicio descritas anteriormente para sujetos adultos con hipertensión arterial. Esta prescripción de ejercicio ha mostrado grandes beneficios para la salud

cardiometabólica, la composición corporal y la condición física en este tipo de población.

Cada sesión de entrenamiento tendrá una duración de 60 min aproximadamente y estará dividida en tres fases que se pueden ver de forma resumida en la tabla 3.

5.26.1. **Fase Preparatoria al Entrenamiento**

Esta primera fase tiene una duración de unos 10 min y estará dividida en un calentamiento general y un calentamiento específico. El calentamiento general incluirá 5 min de marcha nórdica en bicicleta elíptica; ejercicios de movilidad articular de miembros superiores e inferiores y estiramientos dinámicos. El calentamiento específico incluirá dos ejercicios globales, un squat y un press banca; el sujeto realizará 2 series por ejercicio solamente con el peso de la barra de entrenamiento (5kg de peso) y descansará 2 min entre series; la primera serie de 8-10 repeticiones y la segunda serie de 6-8 repeticiones.

5.26.2. **Fase Principal**

La segunda fase presenta una una duración de 40 min y estará compuesta por dos unidades de entrenamiento, una de fuerza y otra de resistencia aeróbica. La unidad de entrenamiento de fuerza se realizará durante los primeros 20 min de la sesion y en ella se incluirán 2 ejercicios que reproducen acciones motrices básicas. El primer ejercicio será un empuje de hemisferio inferior del cuerpo, un squat, que cada sujeto realizará a una intensidad del 60% de su 1RM. El volumen de trabajo será de 3 series con un descanso entre cada una de ellas de 3 min. El número de repeticiones por serie será individualizado para cada sujeto mediante el test inicial de perdida de velocidad. El carácter de esfuerzo será bajo-medio. Entre los dos ejercicios también habrá un descanso de 3 min. El segundo ejercicio será un empuje de hemisferio superior del cuerpo, un press banca, que cada sujeto realizará a una intensidad del 50% de su 1RM. El volumen de trabajo será de 3 series con un descanso entre cada una de ellas de 3 min. El número de repeticiones por serie será individualizado para cada sujeto mediante el test inicial de perdida de velocidad. El carácter de esfuerzo será bajo-medio. Como se ha explicado anteriormente, si no

se dispone de las herramientas necesarias para poder estimar la 1RM se puede utilizar la escala OMNI-RES. Los últimos 20 min de la sesión serán para la unidad de entrenamiento de resistencia aeróbica que se realizán en cicloergómetro. El sujeto trabajará con un método continuo extensivo a una intensidad moderada que irá progresando cada 4 semanas: de la semana 1 a la 4 trabajo en zona 1-2 con una intensidad entre el 55%-60% FCresv; de la semana 5 a la 8 trabajo en zona 2 con una intensidad entre el 60%-65% FCresv; y de la semana 9 a la 12 trabajo en zona 2 con una intensidad entre el 65%-70% FCresv.

5.26.3. **Fase de Recuperación**

El tiempo dedicado a la última parte del entrenamiento será de 10 min. Esta fase constará de una vuelta a la calma de unos 3-5 min en la que el sujeto irá recuperándose del esfuerzo con un pedaleo suave sin carga para después pasar a una parte de estiramientos estáticos de unos 5-7 min. Se debe estirar la musculatura con predominancia tónica/postural debido a su estado de tensión permanente y su tendencia al acortamiento para evitar posibles problemas musculoesqueléticos que afecten al sistema locomotor (Chang et al., 2023; Sadler et al., 2017). La musculatura tónica incluye: fibras superiores del trapecio, dorsal ancho y cuadrado lumbar; pectoral, deltoides anterior y bíceps; psoas ilíaco y recto anterior del cuadríceps; abductores; piramidal, isquiosurales y tríceps sural (gemelos y soleo). Se recomienda utilizar la técnica estático pasiva, realizando 3-4 series por estiramiento y la duración por serie será de 20-30 segundos (Bayles, 2023; Liguori & Medicine, 2020).

Tabla 3

Programa de Entrenamiento Combinado Corazón y Salud

Periodo de intervención		12 Semanas
Frecuencia semanal		2 sesiones/semana; 4 unidades de entrenamiento/semana (2 de fuerza; 2 de resistencia)
Unidad de Entrenamiento de Fuerza		
Calentamiento		10 min (3-5 min calentamiento general y 5-7 min calentamiento específico)
Volumen	Nº Ejercicios	2 ejercicios generales (sentadilla y press de banca)
	Nº de Series	3
	Nº Repeticiones	Individualizadas para cada paciente mediante %PV intra-serie
	% Pérdida de velocidad (intra-serie)	Sentadillas: Baja 10% Press de banca: Moderada 15%
Intensidad	% 1RM VMP 1ª Repetición	Sentadillas: 60% de 1RM Press de banca: 50% de 1RM
	Velocidad de Ejecución	Fase concéntrica: máxima posible Fase excéntrica: moderada
Carácter de esfuerzo		Medio-Bajo
OMNI-RES		4-5

Descanso inter-serie	3 min
Selección de Ejercicios	Sentadilla - Press Banca
Método	Progresión Horizontal
Unidad de Entrenamiento de Resistencia Aeróbica	
Volumen	20 min
Intensidad	Progresar cada cuatro semanas del 55% al 70% del VO²máx/FCresv
Zona de Entrenamiento	2
RPE del 0 al 10	Moderada 3-4
Selección de Ejercicios	Cicloergómetro
Método	Entrenamiento continuo extensivo
Vuelta a la calma	10 min (3-5 min vuelta a la calma y 5-7 min estiramientos estáticos pasivos)

Nota. min= minutos; Nº= número; RM= repetición máxima; VO²máx= volumen máximo de oxígeno; FCresv= frecuencia cardiaca de reserva; VMP= velocidad media propulsiva; OMNI-RES= escala de esfuerzo percibido para ejercicios de resistencia; RPE= escala de esfuerzo percibido.

5.27. CONCLUSIONES

El programa de entrenamiento combinado diseñado en el proyecto Corazón y Salud proporciona una guía a los profesionales del ejercicio y la salud basada en la evidencia científica y en los últimos avances sobre prescripción de ejercicio físico

en población con hipertensión arterial; una de las enfermedades no transmisibles más prevalentes de la sociedad actual y responsable de 10,8 millones de muertes al año en el mundo. En este estudio se marcan las pautas a seguir para diseñar un correcto, adecuado y seguro programa de entrenamiento combinado para conseguir los beneficios que proporcionan ambas modalidades de ejercicio, tanto el entrenamiento de fuerza como el de resistencia aeróbica, con el objetivo de mejorar los parámetros hemodinámicos, la composición corporal y la condición física de los sujetos adultos con hipertensión arterial.

VI – DISCUSIÓN

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En la presente tesis doctoral por compendio, se presentan cuatro estudios que evalúan, por un lado, el efecto del entrenamiento multicomponente y la relación dosis respuesta de éste en sujetos adultos con HTA. Por otro lado, comparar los efectos de tres programas de ejercicio físico diferentes (GE1, MICT; GE2, entrenamiento de fuerza combinado con MICT; GE3, entrenamiento de fuerza combinado con HIIT) y un grupo control sobre los parámetros hemodinámicos y metabólicos, la composición corporal y la condición física en adultos con HTA. Y, por último, proporcionar a los profesionales del ámbito de la salud, médicos cardiólogos, cardiólogos del deporte, médicos de atención primaria y CAFyD (Graduados en Ciencias de la Actividad Física y del Deporte), recomendaciones sobre como prescribir de forma precisa, adecuada y segura un programa de ejercicio en adultos con HTA. Estos estudios contribuyen a un mayor conocimiento científico sobre los beneficios del ejercicio físico pautado de forma individualizada para la prevención y el tratamiento de la HTA en la población adulta.

El primer objetivo de la presente tesis doctoral fue conocer los efectos del entrenamiento multicomponente sobre los niveles de presión arterial en adultos con HTA. En esta revisión sistemática con metaanálisis se incluyeron diferentes ensayos controlados aleatorizados en los que se llevaron a cabo intervenciones con programas de entrenamiento combinado, de fuerza y resistencia en la misma sesión, y en los que se mostraron reducciones significativas sobre los niveles de PAS y PAD en adultos con HTA (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al., 2014; Lima et al., 2017; Masroor et al., 2018; Schroeder et al., 2019; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005). Estos hallazgos están en consonancia con otras revisiones sistemáticas y metaanálisis presentes en la literatura actual (Cornelissen & Smart, 2013; Corso et al., 2016; Herrod et al., 2018; Pescatello et al., 2019), que revisaron y analizaron este tipo de intervención con entrenamiento multicomponente para este mismo grupo de población. Además de las mejoras de los marcadores sanguíneos, los trabajos incluidos en la revisión sistemática muestran como esta modalidad de entrenamiento también es efectiva para mejorar la composición corporal, el perfil lipídico y la condición física en adultos con HTA (de Oliveira et al., 2019; Dos Santos et al., 2014; Guimaraes et al.,

2014; Lima et al., 2017; Masroor et al., 2018; Schroeder et al., 2019; Son et al., 2016; Sousa et al., 2013; Stewart et al., 2005). Otro aspecto importante a destacar de este primer estudio es la heterogeneidad que presentan los protocolos de intervención de los distintos ensayos incluidos; esto podría influir en el resultado de las respuestas de la PAS y de la PAD, como se ha podido comprobar en trabajos anteriores, donde indican que la manipulación de las varibles del entrenamiento pueden determiner las respuestas fisiológicas del organismo (Spiering et al., 2008; Taipale & Häkkinen, 2013). En cuanto a los programas de intervención del presente estudio, en relación a la frecuencia de entrenamiento, el resultado del metaanálisis indicó que las reducciones de PAS y PAD mejoraron independientemente del número de días de entrenamiento, siendo 3 días por semana la frecuencia mínima aplicada en los estudios incluidos. Las recomendaciones de ejercicio para la hipertensión del American College of Sports Medicine y las últimas guías clínicas sobre hipertensión apuntan en la misma dirección, siendo 3 días por semana la frecuencia mínima de entrenamiento recomendada (Unger et al., 2020; Zaleski, 2019). En cuanto al entrenamiento aeróbico, todos los grupos obtuvieron reducciones significativas de la PAS y PAD, independientemente del volumen o intensidad de trabajo. Sin embargo, los protocolos que aplicaron 30 min o más de trabajo mostraron mayores reducciones de la PAS. Las principales guías clínicas de cardiología e hipertensión establecen un mínimo de 30 min al día de ejercicio aeróbico, tiempo asociado a reducciones de 7 mmHg para la PAS y 5 mmHg para la PAD, coincidiendo estas guías con los resultados obtenidos en este metaanálisis (Unger et al., 2020). Respecto a los protocolos utilizados para el trabajo de fuerza, el metaanálisis reveló que un número inferior o igual a 10 repeticiones produjo mayores reducciones de la PAS y que sólo el trabajo superior al 75% de 1 RM produjo mejoras en esta variable. La respuesta de la PAD fue la misma independientemente de la intensidad de trabajo y el número de repeticiones. En este sentido, se deduce que un protocolo de entrenamiento de fuerza de menor volumen y mayor intensidad podría tener una mayor influencia sobre la presión arterial en sujetos con hipertensión, pero estos resultados son controvertidos en cuanto a la intensidad del entrenamiento, dado que existen trabajos recientes en la literatura que han demostrado mayores reducciones de presión arterial con intensidades de entrenamiento inferiores al 75% de la 1RM (Correia et al., 2023; López-Ruiz et al., 2025; Paluch et al., 2024). Es necesario seguir avanzando en esta

línea de investigación con nuevos estudios para poder conocer con mayor precisión cual sería la dosis mínima efectiva capaz de reducir los niveles de presión arterial en este grupo de población, pues intensidades altas, superiores al 75% de 1RM, suponen un grado de esfuerzo alto muy alto y pueden comprometer la seguridad del sujeto y la adherencia del mismo al entrenamiento (Bonilla et al., 2022; Bukhary et al., 2023; Kemler et al., 2022).

En relación con el orden de los componentes del ejercicio, el presente metaanálisis no mostró diferencias significativas. Algunos estudios, como los de Eklund et al. (2016), Schumann et al. (2014) o Wilhelm et al. (2014), pueden explicar estos resultados. En sus trabajos, con diferentes tipos de poblaciones, mujeres sedentarias, adultos mayores sedentarios y hombres jóvenes activos, se observó que el orden de los componentes en los programas de entrenamiento multicomponente no afectaba a las adaptaciones de cada modalidad. En esta línea, también existen publicaciones que indican que puede haber interferencia entre las adaptaciones de las distintas modalidades de entrenamiento al unirlas en la misma sesión. Sin embargo, en población sedentaria o sujetos que comienzan con un programa de entrenamiento se ha visto que esto no influye y únicamente podría ser relevante en poblaciones deportistas o de competición (Coffey & Hawley, 2017; Schumann et al., 2022).

El segundo objetivo de la presente tesis doctoral fue conocer los efectos de un programa de entrenamiento de resistencia frente al entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con MICT sobre los niveles de PAS, PAD, PAM, PP, DP; colesterol total, HDL, LDL, triglicéridos y glucosa; fuerza máxima de hemisferio superior e inferior del cuerpo; y capacidad cardiorrespiratoria en adultos con HTA. Uno de los principales hallazgos de este estudio fue que el grupo de entrenamiento combinado obtuvo mayores reducciones en SBP, DBP y MAP que el grupo de entrenamiento cardiovascular, de hasta -12,8 mmHg, -6,8 mmHg y -8,6 mmHg respectivamente. Estas mejoras pueden deberse a diferentes mecanismos como la función y la estructura vascular dependiente del endotelio y de la regulación del sistema nervioso simpatico, factores que se ven alterados y pueden contribuir a la elevación de la PA (Drożdż et al., 2023; Grassi et al., 2018; Mancia & Grassi, 2014; Mancia et al., 2023). La disfunción endotelial es determinante en la función vascular y depende, en gran medida, de la

biodisponibilidad de óxido nítrico (NO), que induce la relajación de los vasos sanguíneos y regula la PA (Gamboa et al., 2007; Node et al., 1997). El entrenamiento de fuerza puede actuar como regulador en la biodisponibilidad de NO aumentando la AMPK/PPARδ vascular y suprimiendo el estrés del retículo endoplásmico consiguiendo así mejorar y mantener la función endotelial (Cheang et al., 2017; Tian & Meng, 2019). Estos resultados pueden estar en consonancia con estudios anteriores que mostraron como el entrenamiento de fuerza mejoró significativamente la función endotelial en diferentes grupos de población (Ashor et al., 2015; Zhang et al., 2021). Por otra parte, en pacientes con HTA es común encontrar una sobreactivación del sistema nervioso simpático y una reducción del control del parasimpático (Fisher & Paton, 2012; Mancia & Grassi, 2014). Este desajuste fisiológico también puede ser normalizado y regularizado por el entrenamiento de fuerza como ya mostraron investigaciones previas (Laterza et al., 2007; Trevizani et al., 2018). En cuanto a la composición corporal, ambos grupos mostraron mejoras significativas frente al grupo control. No obstante, es importante destacar que los participantes que realizaron entrenamiento combinado obtuvieron mayores reducciones de perímetro abdominal que los participantes que realizaron entrenamiento de resistencia exclusivamente. Estos resultados pueden obedecer a que el entrenamiento de fuerza favorece la perdida de grasa visceral promoviendo adaptaciones metabólicas en el tejido adiposo subcutáneo abdominal con un aumento significativo de la lipólisis en esa zona tanto durante como tiempo después del entrenamiento (Khalafi et al., 2021; Wewege et al., 2022). Los valores de glucosa se redujeron significativamente tras la intervención en ambos grupos de intervención frente al grupo control, independientemente del tipo de entrenamiento. Esta mejora podría deberse a que el ejercicio es capaz de mejorar la sensibilidad a la insulina desde la primera sesión de entrenamiento y mejorar la homeostasis general de la glucosa (Mul et al., 2015). En relación a las variables de la condición física, los participantes de ambos grupos mostraron mejoras tanto en la fuerza como en la capacidad cardiorrespiratoria. Respecto a la fuerza, destacar que el grupo de entrenamiento combinado obtuvo mayores mejoras de fuerza máxima en las extremidades superiores e inferiores que el grupo de entrenamiento de resistencia. Estos resultados pueden responder a la especificidad del entrenamiento de fuerza que provocó mayores adaptaciones del sistema nervioso central gracias un mayor reclutamiento de unidades motoras, una mejor

sincronización de estas y a la frecuencia del estímulo, como ya se ha demostrado en la literatura (Del Vecchio et al., 2019; Del Vecchio et al., 2024; Enoka, 1997; Folland & Williams, 2007; Sale, 1988; Schoenfeld et al., 2021). La capacidad cardiorrespiratoria también mejoró significativamente tras finalizar los programas de ejercicio en ambos grupos. Si bien en la literatura hay controversia respecto a que el entrenamiento combinado puede generar interferencias en las adaptaciones inducidas por las distintas vías metabólicas, AMPK activada con entrenamiento de resistencia y m-TOR activada con entrenamiento de fuerza, sin embargo, en el presente estudio se puede observar como los participantes que realizaron el entrenamiento combinado mostraron mayores mejoras en el VO2pico que los participantes que realizaron el entrenamiento de resistencia. Resultados que podrían justificarse por la gran reserva adaptativa que poseen los sujetos sedentarios ante cualquier programa de entrenamiento. Se ha podido comprobar en trabajos anteriores que cuando un sujeto previamente sedentario comienza un programa de entrenamiento combinado la respuesta a las dos modalidades de ejercicio es positiva y aditiva, promoviendo una adaptación genérica en ausencia de una verdadera especificidad del efecto de entrenamiento (Coffey & Hawley, 2017; Pareja-Blanco, Rodríguez-Rosell, et al., 2017). Otro factor importante a considerar es la intensidad o grado de esfuerzo planteado en el entrenamiento de fuerza. Una intensidad baja-moderada y un bajo grado de fatiga explicaría que la posible interferencia también lo fuera, consiguiendo que las respuestas respecto al mantenimiento de las fibras MHC IIX fuera mayor (de Souza et al., 2013; Pareja-Blanco, Rodríguez-Rosell, et al., 2017).

El tercer objetivo de la presente tesis doctoral fue conocer los efectos de un programa de entrenamiento de resistencia frente al entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con MICT; y, frente al entrenamiento de fuerza, basado en la valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con HIIT sobre los niveles de PAS, PAD, PAM, PP, DP; colesterol total, HDL, LDL, triglicéridos y glucosa; fuerza máxima de hemisferio superior e inferior del cuerpo; y capacidad cardiorrespiratoria en adultos con HTA. Uno de los principales hallazgos de esta investigación fue que ambos grupos con entrenamiento combinado mostraron mayores mejoras en todas las variables de estudio, siendo el entrenamiento de fuerza, basado en una

valoración mediante la relación carga-velocidad individual, combinado con MICT el que mayores beneficios mostró. Se puede observar que las reducciones de los niveles de presión arterial obtenidos en este estudio fueron significativamente mayores que los resultados obtenidos en trabajos previos con esta misma modalidad de entrenamiento, a pesar de que la frecuencia de entrenamiento fue menor (López-Ruiz et al., 2023; Pescatello et al., 2019). Estas mejoras podrían estar vinculadas a la rigurosidad con la que se cuantificó la intensidad y el volumen del entrenamiento de fuerza, que proporcionó un grado de esfuerzo similar para todos los participantes (Badillo, 2017; Badillo & Serna, 2002; González-Badillo & Sánchez-Medina, 2010; González-Badillo et al., 2022; Sánchez-Medina & González-Badillo, 2011). Los mayores cambios en los grupos de entrenamiento combinado se pueden atribuir a una mejora en la función endotelial inducida por el entrenamiento de fuerza. El endotelio juega un papel importante en la modulación contráctil vascular que depende en gran medida de la biodisponibilidad del óxido nítrico (NO) (Gamboa et al., 2007; Node et al., 1997; Vallance et al., 1989). Cuando el endotelio está dañado neutraliza la producción de NO y estimula la producción de sustancias vasoconstrictoras, lo que lleva a un aumento de la presión arterial (Brandes, 2014; Schulz et al., 2011). El entrenamiento de fuerza puede estimular la producción de NO al aumentar la AMPK/PPARδ vascular y suprimir el estrés del retículo endoplásmico, mejorando así la función endotelial (Boeno et al., 2020; Pedersen & Febbraio, 2012; Silva et al., 2021; Tian & Meng, 2019). Además, aunque los dos grupos de entrenamiento combinado tuvieron la misma dosis de entrenamiento de fuerza, el grupo que realizó MICT mostró mayores mejoras que el grupo que realizó HIIT. Esto puede deberse, por un lado, a que el ejercicio continuo de moderada intensidad tiene efectos beneficiosos sobre la función endotelial en cortos periodos de intervención, algo que ya ha sido demostrado en trabajos anteriores (Shenouda et al., 2017; Tao et al., 2023; You et al., 2021). Y, por otro lado, a que es difícil saber con certeza la efectividad del entrenamiento HIIT en cortos periodos de tiempo. Se desconocen los efectos reales del HIIT en su aplicación a largo plazo, dado que la validez ecológica de la mayoría de los estudios sobre esta modalidad de entrenamiento se debilita debido a los cortos periodos de intervención en laboratorio, que suelen ser de 8 a 12 semanas de entrenamiento (Coates et al., 2023; Poon et al., 2024).

En cuanto a las variables de composición corporal, masa magra y perímetro de cintura, los participantes de los grupos con entrenamiento de fuerza mostraron las mayores mejoras en estas variables, siendo nuevamente el grupo de fuerza combinado con MICT el que obtuvo los mayores beneficios. Estos resultados pueden atribuirse al entrenamiento de fuerza, que favorece la pérdida de grasa visceral al promover adaptaciones metabólicas en el tejido adiposo subcutáneo abdominal, con un aumento significativo de la lipólisis en esta zona, tanto durante como después del entrenamiento (Khalafi et al., 2021; Severinsen & Pedersen, 2020; Wewege et al., 2022). En esta línea, se puede observar que todos los grupos de intervención también redujeron significativamente los valores de colesterol total, LDL y glucosa. Estas mejoras pueden ser provocadas por la liberación de IL-6 durante el ejercicio, entre otras exerquinas, ya que su señalización dentro del músculo conduce a un aumento de la captación basal de glucosa y la translocación de su transportador GLUT-4 (Pedersen & Febbraio, 2008, 2012; Severinsen & Pedersen, 2020), además de aumentar la oxidación de ácidos grasos intramiocelular o de todo el cuerpo a través de la activación de AMPK (Pedersen & Febbraio, 2008, 2012; Severinsen & Pedersen, 2020).

En relación a la condición física, los tres grupos de intervención mostraron mejoras significativas respecto al GC, pero fue el grupo de entrenamiento de fuerza combinado con MICT el que mostró mayores ganancias de fuerza máxima en miembros superiores e inferiores y capacidad cardiorrespiratoria. Estos resultados pueden ser una respuesta al entrenamiento de fuerza, que logra mayores adaptaciones neurales a través del aumento del reclutamiento y sincronización de unidades motoras y la frecuencia de estímulo (Del Vecchio et al., 2019; Enoka, 1997; D. G. Sale, 1988), unido al entrenamiento MICT, dado que las adaptaciones neurales de los diferentes grupos de intervención estuvieron determinadas por el tipo de actividad realizada, la intensidad del trabajo y la duración de la acción (Badillo & Serna, 2002). Estos resultados pueden justificarse por la gran capacidad adaptativa que tienen los sujetos sedentarios al inicio de cualquier programa de ejercicio físico. Estudios previos han demostrado que los sujetos sedentarios que comienzan un programa de entrenamiento combinado de fuerza y resistencia consiguen una respuesta positiva y aditiva a las dos modalidades de ejercicio, favoreciendo una adaptación genérica en ausencia de una verdadera especificidad del efecto del

entrenamiento (Coffey & Hawley, 2017; Pareja-Blanco, Rodríguez-Rosell, et al., 2017).

Finalmente, **el cuarto objetivo** de la presente tesis doctoral fue porcionar recomendaciones a los profesionales de la salud y del ejercicio físico (médicos y CAFyD) para poder cuantificar de forma adecuada, segura y lo más precisa posible el estímulo o carga de trabajo en los programas de entrenamiento combinado para adultos con HTA. Para ello, se han desarrollado unas recomendaciones para la prescripción de entrenamiento combinado en adultos con HTA, con la intención de proporcionar herramientas a los profesionales del ejercicio físico que ayuden con un adecuado diseño de los programas de entrenamiento. Las guías clínicas más importantes de cardiología e hipertensión marcan directrices generales de prescripción de ejercicio físico para población adulta con HTA (Charchar et al., 2024; Mancia et al., 2023; Pelliccia et al., 2020; Unger et al., 2020; Whelton et al., 2018a), pero estas recomendaciones simplemente indican la frecuencia, el tipo de entrenamiento y la intensidad, sin profundizar en el resto de variables del entrenamiento; respecto a la intensidad, las indicaciones son de intensidad moderada y/o vigorosa, sin aclarar la forma de cuantificar la carga de trabajo. La fortaleza de este estudio radica en intentar solventar esta problemática, ofreciendo la información necesaria sobre la interferencia de los distintos fármacos antihipertensivos con el ejercicio (Khalil & Zelster, 2020; Laurent, 2017; Pelliccia et al., 2020); la respuesta de la presión arterial durante y post ejercicio (Nayor et al., 2023; Pesova et al., 2023); y, por último, las pautas para una dosificación adecuada y lo más precisa posible del estímulo o carga de entrenamiento, teniendo en cuanta todas las variables del mismo (Badillo & Serna, 2002; Bull et al., 2020; Elvar & García-Orea, 2019; McEvoy et al., 2024). Este documento de recomendaciones expone, por un lado, las pautas para la prescripción de entrenamiento individualizado de ambas modalidades (resistencia y fuerza) de manera selectiva, como única modalidad de entrenamiento. Y, por otro lado, las pautas para la prescripción de un entrenamiento combinado de ambas modalidades en la misma sesión, concluyendo a modo de ejemplo con las recomendaciones de ejercicio físico del ensayo clínico Corazón y Salud, llevado a cabo para la presente tesis doctoral.

Por un lado, para el entrenamiento de resistencica se plantean las siguientes recomendaciones: una frecuencia mínima de 2 días por semana; una intensidad de entrenamiento moderada, entre el 55%-70% del VO²máx o FCresv, lo que se conoce

como zona 2; intensidades que ya han sido estudiadas en trabajos anteriores y que han demostrado su beneficio a nivel metabólico (Riddell et al., 2017; San-Millán, 2023). El volumen de entrenamiento para este objetivo y tipo de población será de 150 a 300 minutos por semana, estando en consonancia con las últimas recomendaciones del la OMS o guías clínicas sobre el manejo de la HTA (Bull et al., 2020; McEvoy et al., 2024); el tipo de actividad debe implicar grandes grupos musculares, movimientos cíclicos y mantenidos durante un medio-largo periodo de tiempo, como pedalear o correr. Por otro lado, las recomendaciones para el entrenamiento de fuerza serán: una frecuencia mínima de 2 días por semana no consecutivos; el tiempo por sesión dependerá del número de ejercicios seleccionados, así como del número de series y repeticiones determinadas para dicho entrenamiento. Se deben incluir ejercicios poliarticulares que impliquen grandes grupos musculares que simulen actividades de la vida diaria (sentadillas, press banca, etc); el número de ejercicios por sesión se deben progresar de 6 hasta 8-10 ejercicios, siguiendo la línea de estudios anteriores en este grupo de población (López-Ruiz et al., 2023; Pescatello, 2020). La intensidad se cuantificará a través de la velocidad de ejecución mediante un test de cargas progresivas para estimar la 1RM, de manera segura y precisa, y determinar la intensidad relativa de trabajo (Badillo & Serna, 2002; Elvar & García-Orea, 2019). Con respecto al volumen se debe concretar el número de repeticiones mediante un test de porcentaje de la perdida de velocidad intra-serie con respecto a la primera repetición; la magnitud de perdida de velocidad debe ser baja-moderada, entre un 10%-20%, dado que porcentajes más altos de perdida de velocidad no se asocian con mayores beneficios y puede suponer un importante predictor de estrés metabólico y hormonal que provoca reducciones de la capacidad física y el rendimiento del sujeto (Badillo & Serna, 2002; Rodríguez-Rosell et al., 2021; Rodríguez-Rosell, Yáñez-García, Mora-Custodio, Torres-Torrelo, et al., 2020). En caso de no disponer de un dispositivo para medir la velocidad de ejecución se realizará de manera subjetiva mediante el carácter de esfuerzo (CE), como factor de ajuste de la intensidad del entrenamiento, en función del número de repeticiones (Badillo & Serna, 2002; Elvar & García-Orea, 2019). El CE expresa la relación entre lo realizado y lo realizable, es decir, entre el número de repeticiones realizadas por el sujeto y el número de repeticiones máximas que podría realizar en una serie con la carga propuesta (Badillo & Serna, 2002; Elvar & García-Orea, 2019). Esta forma de cuantificar la dosis de ejercicio, es decir la intensidad y el volumen, está en consonancia con otros trabajos realizados en población mayor, cancer o esclerosis múltiple (Andreu-Caravaca et al., 2020; Díez-Fernández et al., 2023; Marcos-Pardo et al., 2019). Por último, las

recomendaciones para una prescipción adecuada de un entrenamiento combinado de fuerza y resistencia en la misma sesión en adultos con HTA mantendrán las mismas premisas indicadas anteriormente, con la diferencia del tiempo dedicado a cada una de ellas, que será menor. La sesión tendrá una duración de 60 min, aproximadamente, y se estructurará de la siguiente manera: 10 min de calentamiento dividido en dos partes, una general y otra específica; 40 min para la parte principal, los primeros 20 min serán para el entrenamiento de fuerza y los últimos 20 min para el entrenamiento de resistencia; por último, 10 min de vuelta a la calma y estiramientos.

VII – CONCLUSIONES

VII - CONCLUSIONES

7.1. CONCLUSIONES GENERALES

En respuesta al primer objetivo, según la literatura científica analizada, se concluye que los programas de entrenamiento multicomponente son efectivos para reducir los niveles de PAS y PAD en adultos con HTA.

Respecto al segundo objetivo, según los hallazgos de nuestro ensayo clínico, se concluye que todos los programas de intervención, MICT, fuerza combinado con MICT y fuerza combinado con HIIT, son efectivos para conseguir mejoras significativas sobre los parámetros hemodinámicos, perfil lipídico, composición corporal y condición física en adultos con HTA, siendo el grupo de fuerza combinado con MICT el que mayores beneficios mostró.

7.2. CONCLUSIONES ESPECÍFICAS

Los programas de entrenamiento multicomponente reducen significativamente los niveles de PAS y PAD en adultos con HTA. La dosis más efectiva, según el metaanálisis, será un programa de intervención superior a 14 semanas, 3 días/semana y 60 min/sesión. Respecto a las intensidades de entrenamiento, la intensidad del entrenamiento aeróbico estará alrededor del 75% de la FC de reserva y la intensidad del entrenamiento de fuerza será mayor al 75% de 1 RM, con 10 repeticiones como máximo por serie.

El entrenamiento con MICT y el entrenamiento de fuerza combinado con MICT con una duración de 12 semanas, 2 días/semana y 60 min/sesión muestran mejoras significativas sobre los niveles de PAS, PAD, PAM, PP, DP; colesterol total, HDL, LDL, triglicéridos y glucosa; fuerza máxima de hemisferio superior e inferior del cuerpo; y capacidad cardiorrespiratoria frente al grupo control en adultos con HTA. El hallazgo principal de este estudio fue que el grupo de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con MICT obtuvo mayores beneficios sobre todas las variables dependientes que el grupo que realizó solamente MICT.

El entrenamiento con MICT, el entrenamiento de fuerza combinado con MICT y el entrenamiento de fuerza combinado con HIIT realizado durante 12 semanas, 2 días/semana y 60 min/sesión presenta mejoras significativas sobre los niveles de PAS, PAD, PAM, PP, DP; colesterol total, HDL, LDL, triglicéridos y glucosa; fuerza máxima de hemisferio superior e inferior del cuerpo; y capacidad cardiorrespiratoria frente al grupo control en adultos con HTA. El hallazgo principal de este estudio fue que el grupo de entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con MICT obtuvo mayores beneficios sobre todas las variables dependientes que el grupo que realizó solamente MICT y que el grupo de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado con HIIT.

En este último documento quedan reflejadas las recomendaciones para el diseño de un programa de entrenamiento combinado, de fuerza y resistencia en la misma sesión, para adultos con HTA de forma adecuada, segura y lo más precisa posible que servirá de ayuda a los profesionales de la salud y del ejercicio físico (médicos y CAFyD). La frecuencia mínima de entrenamiento será de 2-3 días/semana no consecutivos, con sesiones ≤60 minutos en las que se realizarán ambas modalidades. Para el entrenamiento de fuerza se incluirán de 6 a 8-10 ejercicios que impliquen grandes grupos musculares (sentadillas, press banca, etc.); la intensidad será baja-moderada y se cuantificará a través de la velocidad de ejecución; el nº de repeticiones se individualizará para cada persona mediante un test de porcentaje de la pérdida de velocidad intra-serie con respecto a la 1ª repetición, un 10-20% de PV. Para el entrenamiento de resistencia, la intensidad está entre el 55%-70% del VO²máx o FCresv (zona 2); el volumen mínimo de entrenamiento será de 20-30 min; y el tipo de actividad debe implicar grandes grupos musculares, movimientos cíclicos y mantenidos durante un medio-largo periodo de tiempo, como pedalear o correr.

VIII – APLICACIONES PRÁCTICAS

VIII - APLICACIONES PRÁCTICAS

Las aplicaciones prácticas derivadas de la presente tesis doctoral tienen grandes beneficios para la salud cardiometabólica y la calidad de vida de las personas adultas con hipertensión arterial. La prescripción adecuada e individualizada de programas de entrenamiento combinado de fuerza y resistencia en la misma sesión es una terapia efectiva coadyuvante para poder frenar el desarrollo de la enfermedad cardiovascular a través de la mejora de sus factores de riesgo y con ello las muertes por esta causa.

A continuación, se detallan las principales aplicaciones prácticas producto de los hallazgos de los trabajos presentados:

1. Los resultados obtenidos respaldan la mejora significativa de los niveles de presión arterial, tanto sistólica como diastólica, con intervenciones de entrenamiento combinado en la misma sesión en adultos con HTA. Las instituciones públicas deben ser las primeras interesadas en promover la prescripción de esta modalidad de entrenamiento desde la atención primaria para la prevención y tratamiento de este trastorno que supone el principal factor de riesgo modificable de causa de muerte cardiovascular a nivel mundial. Sería necesario crear unidades de HTA en los centros de salud de atención primaria que ayudarían a modificar importantes factores conductuales en este grupo de población, como son el sedentarismo y la inactividad física, ayudando con ello a frenar la progresión de la enfermedad cardiovascular y sus posibles eventos adversos.
2. Se proporciona la relación dosis-respuesta efectiva de entrenamiento combinado en la misma sesión para conseguir mejorar los parámetros hemodinámicos, perfil lipídico, niveles de glucosa, composición corporal y condición física en adultos con HTA. Además, se facilitan nuevos protocolos para la dosificación del estímulo o carga de entrenamiento nunca antes utilizados en este grupo de población de manera adecuada, segura y con la máxima precisión posible. Se aportan nuevas herramientas para la cuantificación de la carga, como la velocidad de

ejecución en el trabajo de fuerza o la potencia en el trabajo de resistencia, que permiten conocer e igualar el grado de esfuerzo programado, aplicado y realizado por cada persona, consiguiendo realmente una individualización del entrenamiento.

3. Sería conveniente incluir a los Graduados en Ciencias de la Actividad Física y el Deporte (CAFyD) en los equipos multidisciplinares del ámbito clínico o en su defecto derivar a los pacientes a los centros de acondicionamiento físico para que sean asesorados por los mismos. La prescripción de los programas de entrenamiento combinado en la misma sesión debe ser programada y supervisada por el profesional del ejercicio físico (CAFyD), dado que debe ir acompañada de una evaluación de la persona y una programación del entrenamiento continua que permita conocer el efecto de la carga aplicada y asegurar efectividad y control de los entrenamientos. En la presente tesis doctoral se proporciona a los entrenadores y educadores físico-deportivos las recomendaciones y protocolos necesarios para un correcto diseño de los programas de entrenamiento, tanto selectivo como combinado en la misma sesión, en personas adultas con HTA y poder garantizarles así la mejora de la salud cardiometabólica y condición física.

IX - LIMITACIONES Y FUTURAS LÍNEAS DE INVESTIGACIÓN

IX - LIMITACIONES Y FUTURAS LÍNEAS DE INVESTIGACIÓN

La presente tesis doctoral presenta nuevas aportaciones a la comunidad científica sobre los beneficios del ejercicio físico, que ayudará como terapia coadyuvante, para el control y el tratamiento de la HTA y la enfermedad cardiovascular. Entre las diferentes aportaciones se encuentran, por un lado, el primer estudio realizado en población con HTA que compara el entrenamiento selectivo MICT frente al entrenamiento de fuerza, basado en una valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con MICT; y, frente al entrenamiento de fuerza, basado en la valoración mediante la relación carga-velocidad individual, combinado en la misma sesión con HIIT. Por otro lado, estaría la cuantificación de la intensidad y el volumen de entrenamiento a través de la velocidad de ejecución, nunca antes utilizada en este grupo de población, lo que permitió conocer e individualizar la carga de trabajo con la mayor precisión posible consiguiendo que el estímulo programado para el entrenamiento de fuerza fuese realmente el aplicado y el realizado por cada participante. Además, es importante resaltar que esta cuantificación de la carga permitió que el grado de fatiga alcanzado por cada participante fuese prácticamente el mismo durante todo el periodo de intervención.

A pesar de las aportaciones al conocimiento científico sobre los beneficios del entrenamiento combinado de fuerza y resistencia en la misma sesión sobre la mejora de la HTA, el presente estudio también presenta ciertas limitaciones que pueden haber influido en los resultados y su interpretación. Abordar estas limitaciones en investigaciones futuras fortalecería la validez de los hallazgos actuales y proporcionaría una comprensión más amplia y precisa de los efectos del entrenamiento combinado de fuerza y resistencia en la misma sesion sobre la mejora de los niveles de presión arterial y la calidad de vida de la población adulta con HTA. A continuación, se detallan las principales limitaciones identificadas en la presente tesis doctoral.

La revision sistemática con metaanálisis presentada en esta tesis doctoral sobre los efectos del entrenamiento multicomponente en adultos con hipertesión arterial proporciona una evaluación de la evidencia disponible más rigurosa, permitiendo una mejor comparación de los resultados de múltiples estudios y

fortaleciendo las conclusiones. Sin embargo, las principales limitaciones de este estudio son el escaso número de ECAs que existen en la actualidad sobre esta cuestión; la heterogeneidad de la población incluida (sexo y edad); la heterogeneidad de los protocolos aplicados en las distintas intervenciones; el tipo de ejercicio-os realizados en el entrenamiento aeróbico y de fuerza; y el tamaño muestral, que era pequeño en algunos estudios. Estos aspectos limitan las comparaciones entre los diferentes grupos de intervención e indican la necesidad de nuevos estudios que aporten nuevos datos que permitan generalizar los resultados.

Respecto a las limitaciones de los estudios resultantes del ensayo clínico, por un lado, estaría el tiempo total de intervención. Es posible que períodos más largos de tiempo de entrenamiento conduzcan a resultados distintos entre los diferentes grupos de intervención o más significativos en algunas de las variables. Por otro lado, la falta de un grupo de intervención que realizara unicamente entrenamiento de fuerza sería otra consideración para futuras investigaciones. Este grupo selectivo de fuerza se podría haber comparado con el resto de modalidades de entrenamiento del estudio y se podría haber conocido con mayor precisión los efectos de las distintas intervenciones sobre los niveles de presión arterial. Por último, el no controlar la ingesta diaria de los participantes también sería otra de las limitaciones del estudio.

Teniendo en cuenta las presentes limitaciones y a partir de los hallazgos y conclusiones, se identifican diversas áreas de investigación para seguir avanzando en el conocimiento sobre el ejercicio y la salud cardiovascular. A continuación, se presentan diferentes líneas y acciones que podrían tenerse en cuenta para futuros estudios.

Realizar estudios controlados con periodos de intervención superiores a 12 semanas donde se evaluen los efectos de diferentes programas de entrenamiento sobre los parámetros hemodinámicos y metabólicos, composición corporal y condición física en adultos con hipertensión arterial. Después se podrían confrontar los resultados obtenidos con estudios previos de 12 semanas y comparar la respuesta de los diferentes programas de ejercicio sobre las diferentes variables planteadas.

Por otro lado, también sería interesante desarroyar un ensayo controlado en este grupo de población en el que se pueda valorar diferentes intervenciones con entrenamiento de fuerza, un grupo programado a través de la velocidad de ejecución y otro grupo programado de manera tradicional a través de la 1RM y un número determinado de repeticiones, y comparar los efectos sobre los parámetros hemodinámicos y metabólicos, composición corporal y condición física en adultos con hipertensión arterial. Esto permitiría conocer con mayor precision las diferentes respuestas del ejercicio sobre las variables descritas.

En relación al entrenamiento de fuerza, también sería interesante realizar un estudio en población adulta con hipertensión arterial para conocer los efectos agudos sobre el grado de fatiga alcanzado durante un entrenamiento de fuerza programando el volumen, por un lado, a través de la perdida de velocidad, y, por otro lado, de manera tradicional, con un número concreto de repeticiones.

Por ultimo, se podría llevar a cabo un estudio controlado donde se evaluen los efectos de diferentes programas de entrenamiento sobre los parámetros hemodinámicos y metabólicos, composición corporal y condición física en adultos con hipertensión arterial en el que, además, se llevara el control diario de la alimentación. Esto serviría para conocer cuánto de beneficio de las variables, si lo hubiera, le correspondería al ejercicio físico y cuanto a la alimentación.

X - REFERENCIAS BIBLIOGRÁFICAS

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Adami, P. E., Koutlianos, N., Baggish, A., Bermon, S., Cavarretta, E., Deligiannis, A.,…Papadakis, M. (2022). Cardiovascular effects of doping substances, commonly prescribed medications and ergogenic aids in relation to sports: a position statement of the sport cardiology and exercise nucleus of the European Association of Preventive Cardiology. *European Journal of Preventive Cardiology*, *29*(3), 559-575. https://doi.org/10.1093/eurjpc/zwab198

Akimoto, T., Pohnert, S. C., Li, P., Zhang, M., Gumbs, C., Rosenberg, P. B.,…Yan, Z. (2005). Exercise stimulates Pgc-1alpha transcription in skeletal muscle through activation of the p38 MAPK pathway. *J Biol Chem*, *280*(20), 19587-19593. https://doi.org/10.1074/jbc.M408862200

Albalawi, H., Coulter, E., Ghouri, N., & Paul, L. (2017). The effectiveness of structured exercise in the south Asian population with type 2 diabetes: a systematic review. *Phys Sportsmed*, *45*(4), 408-417. https://doi.org/10.1080/00913847.2017.1387022

Allen, H., Coggan, A. R., & McGregor, S. (2019). *Training and racing with a power meter*. VeloPress.

Alvarez, C., Peñailillo, L., Ibacache-Saavedra, P., Jerez-Mayorga, D., Campos-Jara, C., Andrade, D. C.,…Gurovich, A. N. (2024). Six weeks of a concurrent training therapy improves endothelial function and arterial stiffness in hypertensive adults with minimum non-responders. *Hipertens Riesgo Vasc*. https://doi.org/10.1016/j.hipert.2024.07.001

Alves, A. J., Wu, Y., Lopes, S., Ribeiro, F., & Pescatello, L. S. (2022). Exercise to Treat Hypertension: Late Breaking News on Exercise Prescriptions That FITT. *Curr Sports Med Rep*, *21*(8), 280-288. https://doi.org/10.1249/jsr.0000000000000983

Amare, F., Kiflu, A., & Taddese, A. (2025). Effects of concurrent continuous aerobic and short rest resistance exercise training on metabolic biomarkers in type 2 diabetes patients: a systematic review and meta-analysis. *Diabetol Metab Syndr*, *17*(1), 290. https://doi.org/10.1186/s13098-025-01838-x

Anandita, M., Mehta, A., Yang, E., & Parapid, B. (2020). Older Adults and Hypertension: Beyond the 2017 Guideline for Prevention, Detection. *Evaluation, and Management of High Blood Pressure in Adults*, *26*.

Andreato, L. V., Esteves, J. V., Coimbra, D. R., Moraes, A. J. P., & de Carvalho, T. (2019). The influence of high-intensity interval training on anthropometric variables of adults with overweight or obesity: a systematic review and network meta-analysis. *Obes Rev*, *20*(1), 142-155. https://doi.org/10.1111/obr.12766

Andreu-Caravaca, L., Ramos-Campo, D. J., Abellán-Aynés, O., & Rubio-Arias, J. (2020). Movement Velocity as A Measure of Exercise Intensity in Persons with Multiple Sclerosis: A Validity Study. *J Clin Med*, *9*(8). https://doi.org/10.3390/jcm9082458

Arnett, D. K., Blumenthal, R. S., Albert, M. A., Buroker, A. B., Goldberger, Z. D., Hahn, E. J.,…Ziaeian, B. (2019). 2019 ACC/AHA Guideline on the Primary

Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*, *140*(11), e596-e646. https://doi.org/10.1161/cir.0000000000000678

Ashor, A. W., Lara, J., Siervo, M., Celis-Morales, C., Oggioni, C., Jakovljevic, D. G., & Mathers, J. C. (2015). Exercise modalities and endothelial function: a systematic review and dose-response meta-analysis of randomized controlled trials. *Sports Med*, *45*(2), 279-296. https://doi.org/10.1007/s40279-014-0272-9

Atakan, M. M., Koşar Ş, N., Güzel, Y., Tin, H. T., & Yan, X. (2021). The Role of Exercise, Diet, and Cytokines in Preventing Obesity and Improving Adipose Tissue. *Nutrients*, *13*(5). https://doi.org/10.3390/nu13051459

Baar, K., Wende, A. R., Jones, T. E., Marison, M., Nolte, L. A., Chen, M.,…Holloszy, J. O. (2002). Adaptations of skeletal muscle to exercise: rapid increase in the transcriptional coactivator PGC-1. *Faseb j*, *16*(14), 1879-1886. https://doi.org/10.1096/fj.02-0367com

Badillo, J. J. G. (2017). *La velocidad de ejecución como referencia para la programación, control y evaluación del entrenamiento de fuerza*. Ergotech.

Badillo, J. J. G., & Serna, J. R. (2002). *Bases de la programación del entrenamiento de fuerza* (Vol. 308). Inde.

Banegas, J. R., Sánchez-Martínez, M., Gijón-Conde, T., López-García, E., Graciani, A., Guallar-Castillón, P.,…Rodríguez-Artalejo, F. (2024). Numerical values and impact of hypertension in Spain. *Rev Esp Cardiol (Engl Ed)*, *77*(9), 767-778. https://doi.org/10.1016/j.rec.2024.03.011

Bavaresco Gambassi, B., Chaves, L. F. C., Sousa, T., Ribeiro, M. J. S., Souza, T. A., & Schwingel, P. A. (2024). Short-duration dynamic power training with elastic bands combined with endurance training: a promising approach to hypertension management in older adults. *J Hypertens*, *42*(4), 735-742. https://doi.org/10.1097/hjh.0000000000003681

Bayles, M. P. (2023). *ACSM's exercise testing and prescription*. Lippincott Williams & Wilkins.

Bird, S. P., Tarpenning, K. M., & Marino, F. E. (2005). Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med*, *35*(10), 841-851. https://doi.org/10.2165/00007256-200535100-00002

Bishop, D. (2003a). Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports Med*, *33*(6), 439-454. https://doi.org/10.2165/00007256-200333060-00005

Bishop, D. (2003b). Warm up II: performance changes following active warm up and how to structure the warm up. *Sports Med*, *33*(7), 483-498. https://doi.org/10.2165/00007256-200333070-00002

Boeno, F. P., Ramis, T. R., Munhoz, S. V., Farinha, J. B., Moritz, C. E. J., Leal-Menezes, R.,…Reischak-Oliveira, A. (2020). Effect of aerobic and resistance exercise training on inflammation, endothelial function and ambulatory blood pressure in middle-aged hypertensive patients. *J Hypertens*, *38*(12), 2501-2509. https://doi.org/10.1097/hjh.0000000000002581

Bonilla, D. A., Cardozo, L. A., Vélez-Gutiérrez, J. M., Arévalo-Rodríguez, A., Vargas-Molina, S., Stout, J. R.,…Petro, J. L. (2022). Exercise Selection and Common Injuries in Fitness Centers: A Systematic Integrative Review and Practical Recommendations. *Int J Environ Res Public Health*, *19*(19). https://doi.org/10.3390/ijerph191912710

Booth, F. W., Ruegsegger, G. N., Toedebusch, R. G., & Yan, Z. (2015). Endurance Exercise and the Regulation of Skeletal Muscle Metabolism. *Prog Mol Biol Transl Sci*, *135*, 129-151. https://doi.org/10.1016/bs.pmbts.2015.07.016

Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scand J Work Environ Health*, *16 Suppl 1*, 55-58. https://doi.org/10.5271/sjweh.1815

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human kinetics.

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med Sci Sports Exerc*, *14*(5), 377-381.

Brandes, R. P. (2014). Endothelial dysfunction and hypertension. *Hypertension*, *64*(5), 924-928. https://doi.org/10.1161/hypertensionaha.114.03575

Brandt, C., & Pedersen, B. K. (2010). The role of exercise-induced myokines in muscle homeostasis and the defense against chronic diseases. *J Biomed Biotechnol*, *2010*, 520258. https://doi.org/10.1155/2010/520258

Brawner, C. A., Ehrman, J. K., Schairer, J. R., Cao, J. J., & Keteyian, S. J. (2004). Predicting maximum heart rate among patients with coronary heart disease receiving beta-adrenergic blockade therapy. *Am Heart J*, *148*(5), 910-914. https://doi.org/10.1016/j.ahj.2004.04.035

Brook, R. D., Appel, L. J., Rubenfire, M., Ogedegbe, G., Bisognano, J. D., Elliott, W. J.,…Rajagopalan, S. (2013). Beyond medications and diet: alternative approaches to lowering blood pressure: a scientific statement from the american heart association. *Hypertension*, *61*(6), 1360-1383. https://doi.org/10.1161/HYP.0b013e318293645f

Brook, R. D., & Rajagopalan, S. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults. A report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Soc Hypertens*, *12*(3), 238. https://doi.org/10.1016/j.jash.2018.01.004

Buch, A., Ben-Yehuda, A., Rouach, V., Maier, A. B., Greenman, Y., Izkhakov, E.,…Eldor, R. (2022). Validation of a multi-frequency bioelectrical impedance analysis device for the assessment of body composition in older adults with type 2 diabetes. *Nutr Diabetes*, *12*(1), 45. https://doi.org/10.1038/s41387-022-00223-1

Bukhary, H. A., Basha, N. A., Dobel, A. A., Alsufyani, R. M., Alotaibi, R. A., & Almadani, S. H. (2023). Prevalence and Pattern of Injuries Across the Weight-Training Sports. *Cureus*, *15*(11), e49759. https://doi.org/10.7759/cureus.49759

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G.,…Willumsen, J. F. (2020). World Health Organization 2020 guidelines on

physical activity and sedentary behaviour. *Br J Sports Med*, *54*(24), 1451-1462. https://doi.org/10.1136/bjsports-2020-102955

Bullard, T., Ji, M., An, R., Trinh, L., Mackenzie, M., & Mullen, S. P. (2019). A systematic review and meta-analysis of adherence to physical activity interventions among three chronic conditions: cancer, cardiovascular disease, and diabetes. *BMC Public Health*, *19*(1), 636. https://doi.org/10.1186/s12889-019-6877-z

Carbone, S., Kirkman, D. L., Garten, R. S., Rodriguez-Miguelez, P., Artero, E. G., Lee, D. C., & Lavie, C. J. (2020). Muscular Strength and Cardiovascular Disease: AN UPDATED STATE-OF-THE-ART NARRATIVE REVIEW. *J Cardiopulm Rehabil Prev*, *40*(5), 302-309. https://doi.org/10.1097/hcr.0000000000000525

Cardozo, G. G., Oliveira, R. B., & Farinatti, P. T. (2015). Effects of high intensity interval versus moderate continuous training on markers of ventilatory and cardiac efficiency in coronary heart disease patients. *ScientificWorldJournal*, *2015*, 192479. https://doi.org/10.1155/2015/192479

Carpes, L., Costa, R., Schaarschmidt, B., Reichert, T., & Ferrari, R. (2022). High-intensity interval training reduces blood pressure in older adults: A systematic review and meta-analysis. *Exp Gerontol*, *158*, 111657. https://doi.org/10.1016/j.exger.2021.111657

Carracedo, J., & Ramírez, R. (2020). Fisiología renal. *Nefrología al día. ISSN*, 2659-2606.

Chang, M. C., Choo, Y. J., Hong, K., Boudier-Revéret, M., & Yang, S. (2023). Treatment of Upper Crossed Syndrome: A Narrative Systematic Review. *Healthcare (Basel)*, *11*(16). https://doi.org/10.3390/healthcare11162328

Charchar, F. J., Prestes, P. R., Mills, C., Ching, S. M., Neupane, D., Marques, F. Z.,…Tomaszewski, M. (2024). Lifestyle management of hypertension: International Society of Hypertension position paper endorsed by the World Hypertension League and European Society of Hypertension. *J Hypertens*, *42*(1), 23-49. https://doi.org/10.1097/hjh.0000000000003563

Cheang, W. S., Wong, W. T., Zhao, L., Xu, J., Wang, L., Lau, C. W.,…Huang, Y. (2017). PPARδ Is Required for Exercise to Attenuate Endoplasmic Reticulum Stress and Endothelial Dysfunction in Diabetic Mice. *Diabetes*, *66*(2), 519-528. https://doi.org/10.2337/db15-1657

Choi, Y., Lee, D. C., Han, Y., Sung, H., Yoon, J., & Kim, Y. S. (2024). Combined association of aerobic and muscle strengthening activity with mortality in individuals with hypertension. *Hypertens Res*, *47*(11), 3056-3067. https://doi.org/10.1038/s41440-024-01788-3

Coates, A. M., Joyner, M. J., Little, J. P., Jones, A. M., & Gibala, M. J. (2023). A Perspective on High-Intensity Interval Training for Performance and Health. *Sports Med*, *53*(Suppl 1), 85-96. https://doi.org/10.1007/s40279-023-01938-6

Coffey, V. G., & Hawley, J. A. (2017). Concurrent exercise training: do opposites distract? *J Physiol*, *595*(9), 2883-2896. https://doi.org/10.1113/jp272270

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences Second Edition*. Lawrence Erlbaum Associates.

Conceição, F., Fernandes, J., Lewis, M., Gonzaléz-Badillo, J. J., & Jimenéz-Reyes, P. (2016). Movement velocity as a measure of exercise intensity in three lower limb exercises. *J Sports Sci*, *34*(12), 1099-1106. https://doi.org/10.1080/02640414.2015.1090010

Cornelissen, V. A., & Smart, N. A. (2013). Exercise training for blood pressure: a systematic review and meta-analysis. *J Am Heart Assoc*, *2*(1), e004473. https://doi.org/10.1161/jaha.112.004473

Correia, R. R., Veras, A. S. C., Tebar, W. R., Rufino, J. C., Batista, V. R. G., & Teixeira, G. R. (2023). Strength training for arterial hypertension treatment: a systematic review and meta-analysis of randomized clinical trials. *Sci Rep*, *13*(1), 201. https://doi.org/10.1038/s41598-022-26583-3

Corso, L. M., Macdonald, H. V., Johnson, B. T., Farinatti, P., Livingston, J., Zaleski, A. L.,…Pescatello, L. S. (2016). Is Concurrent Training Efficacious Antihypertensive Therapy? A Meta-analysis. *Med Sci Sports Exerc*, *48*(12), 2398-2406. https://doi.org/10.1249/mss.0000000000001056

Costa Chaves, L. F., Bavaresco Gambassi, B., Cadore, E. L., Sotão, S., Sousa, T. M., Dias, D. D. S.,…Mostarda, C. (2025). Power exercises with elastic bands combined with endurance training improve pulse pressure, systolic blood pressure, and functional parameters in older adults. *Blood Press Monit*, *30*(2), 49-56. https://doi.org/10.1097/mbp.0000000000000733

Costa, E. C., Hay, J. L., Kehler, D. S., Boreskie, K. F., Arora, R. C., Umpierre, D.,…Duhamel, T. A. (2018). Effects of High-Intensity Interval Training Versus Moderate-Intensity Continuous Training On Blood Pressure in Adults with Pre- to Established Hypertension: A Systematic Review and Meta-Analysis of Randomized Trials. *Sports Med*, *48*(9), 2127-2142. https://doi.org/10.1007/s40279-018-0944-y

Cuadros, L., Ismail, H., & Ho, K. (2017). Evaluation of Reliability of MYZONE MZ-3 Heart Rate Monitor: A Study for the Future of Telephysiotherapy for Preoperative Prehabilitation in Cancer Patients. *Telemed J E Health*, *23*(4), 334-338. https://doi.org/10.1089/tmj.2016.0138

De Mello, W. C., & Danser, A. H. (2000). Angiotensin II and the heart : on the intracrine renin-angiotensin system. *Hypertension*, *35*(6), 1183-1188. https://doi.org/10.1161/01.hyp.35.6.1183

de Morton, N. A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Australian Journal of Physiotherapy*, *55*(2), 129-133. https://doi.org/https://doi.org/10.1016/S0004-9514(09)70043-1

de Morton, N. A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Aust J Physiother*, *55*(2), 129-133. https://doi.org/10.1016/s0004-9514(09)70043-1

de Oliveira, S. N., Pereira Moro, A. R., Polito, M. D., Helena de Jesus, J., & de Souza Bezerra, E. (2019). Effects of Concurrent Training with Elastic Tubes in Hypertensive Patients: A Blind Controlled Randomized Clinical Trial. *Exp Aging Res*, *46*(1), 68-82. https://doi.org/10.1080/0361073x.2019.1693030

de Souza, E. O., Tricoli, V., Roschel, H., Brum, P. C., Bacurau, A. V., Ferreira, J. C.,…Ugrinowitsch, C. (2013). Molecular adaptations to concurrent training. *Int J Sports Med*, *34*(3), 207-213. https://doi.org/10.1055/s-0032-1312627

Del Vecchio, A., Casolo, A., Negro, F., Scorcelletti, M., Bazzucchi, I., Enoka, R.,…Farina, D. (2019). The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. *J Physiol*, *597*(7), 1873-1887. https://doi.org/10.1113/jp277250

Del Vecchio, A., Enoka, R. M., & Farina, D. (2024). Specificity of early motor unit adaptations with resistive exercise training. *J Physiol*, *602*(12), 2679-2688. https://doi.org/10.1113/jp282560

Dempsey, P. C., Larsen, R. N., Dunstan, D. W., Owen, N., & Kingwell, B. A. (2018). Sitting Less and Moving More: Implications for Hypertension. *Hypertension*, *72*(5), 1037-1046. https://doi.org/10.1161/hypertensionaha.118.11190

Dent, E., Morley, J. E., Cruz-Jentoft, A. J., Woodhouse, L., Rodríguez-Mañas, L., Fried, L. P.,…Vellas, B. (2019). Physical Frailty: ICFSR International Clinical Practice Guidelines for Identification and Management. *J Nutr Health Aging*, *23*(9), 771-787. https://doi.org/10.1007/s12603-019-1273-z

Di Raimondo, D., Musiari, G., Miceli, G., Arnao, V., & Pinto, A. (2016). Preventive and Therapeutic Role of Muscle Contraction Against Chronic Diseases. *Curr Pharm Des*, *22*(30), 4686-4699. https://doi.org/10.2174/1381612822666160510125011

Diaz, K. M., & Shimbo, D. (2013). Physical activity and the prevention of hypertension. *Curr Hypertens Rep*, *15*(6), 659-668. https://doi.org/10.1007/s11906-013-0386-8

Dos Santos, E. S., Asano, R. Y., Filho, I. G., Lopes, N. L., Panelli, P., Nascimento Dda, C.,…Prestes, J. (2014). Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: a randomized controlled trial. *J Strength Cond Res*, *28*(11), 3073-3084. https://doi.org/10.1519/jsc.0000000000000537

Doughan, A. K., Harrison, D. G., & Dikalov, S. I. (2008). Molecular mechanisms of angiotensin II-mediated mitochondrial dysfunction: linking mitochondrial oxidative damage and vascular endothelial dysfunction. *Circ Res*, *102*(4), 488-496. https://doi.org/10.1161/circresaha.107.162800

Drożdż, D., Drożdż, M., & Wójcik, M. (2023). Endothelial dysfunction as a factor leading to arterial hypertension. *Pediatr Nephrol*, *38*(9), 2973-2985. https://doi.org/10.1007/s00467-022-05802-z

Díez-Fernández, D. M., Baena-Raya, A., García-Ramos, A., Esteban-Simón, A., Rodríguez-Pérez, M. A., Casimiro-Andújar, A. J., & Soriano-Maldonado, A. (2023). Estimating the one-repetition maximum on the leg-press exercise in female breast cancer survivors. *PeerJ*, *11*, e16175. https://doi.org/10.7717/peerj.16175

Egger, M., Davey Smith, G., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *Bmj*, *315*(7109), 629-634. https://doi.org/10.1136/bmj.315.7109.629

Elvar, J. R. H., & García-Orea, G. P. (2019). *El entrenamiento de la fuerza para la mejora de la condición física y la salud*. Círculo rojo.

Enoka, R. M. (1997). Neural adaptations with chronic physical activity. *J Biomech*, *30*(5), 447-455. https://doi.org/10.1016/s0021-9290(96)00170-4

Escamilla, R. F. (2001). Knee biomechanics of the dynamic squat exercise. *Med Sci Sports Exerc*, *33*(1), 127-141. https://doi.org/10.1097/00005768-200101000-00020

Ferguson, B. (2014). ACSM's Guidelines for Exercise Testing and Prescription 9th Ed. 2014. In *J Can Chiropr Assoc* (Vol. 58, pp. 328). © Jcca 2014.

Fernandes Silva, M. M., Bacal, F., Roque, J. M., Teixeira-Neto, I. S., Carvas Junior, N., Bocchi, E. A., & Guimarães, G. V. (2012). Age-related maximum heart rate among ischemic and nonischemic heart failure patients receiving β-blockade therapy. *J Card Fail*, *18*(11), 831-836. https://doi.org/10.1016/j.cardfail.2012.10.007

Fisher, J. P., & Paton, J. F. (2012). The sympathetic nervous system and blood pressure in humans: implications for hypertension. *J Hum Hypertens*, *26*(8), 463-475. https://doi.org/10.1038/jhh.2011.66

Fleck, S. J., & Kraemer, W. (2014). *Designing resistance training programs, 4E*. Human Kinetics.

Fletcher, G. F., Ades, P. A., Kligfield, P., Arena, R., Balady, G. J., Bittner, V. A.,…Williams, M. A. (2013). Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation*, *128*(8), 873-934. https://doi.org/10.1161/CIR.0b013e31829b5b44

Folland, J. P., & Williams, A. G. (2007). Morphological and neurological contributions to increased strength. *Sports medicine*, *37*, 145-168.

Fox, S. M., 3rd, Naughton, J. P., & Haskell, W. L. (1971). Physical activity and the prevention of coronary heart disease. *Ann Clin Res*, *3*(6), 404-432.

Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects of warming-up on physical performance: a systematic review with meta-analysis. *J Strength Cond Res*, *24*(1), 140-148. https://doi.org/10.1519/JSC.0b013e3181c643a0

Fuchs, F. D., & Whelton, P. K. (2020). High Blood Pressure and Cardiovascular Disease. *Hypertension*, *75*(2), 285-292. https://doi.org/10.1161/hypertensionaha.119.14240

Gallo, G., Volpe, M., & Savoia, C. (2021). Endothelial Dysfunction in Hypertension: Current Concepts and Clinical Implications. *Front Med (Lausanne)*, *8*, 798958. https://doi.org/10.3389/fmed.2021.798958

Gallo, G., Volpe, M., & Savoia, C. (2022). Endothelial Dysfunction in Hypertension: Current Concepts and Clinical Implications. *Front Med (Lausanne)*, *8*, 798958. https://doi.org/10.3389/fmed.2021.798958

Gambassi, B. B., & Schwingel, P. A. (2024). Dynamic power training combined with endurance training reduces arterial stiffness and improves hemodynamic parameters in older adults diagnosed with grade 1 hypertension? *Journal of Hypertension*, *42*(8), 1461-1462.

Gamboa, A., Shibao, C., Diedrich, A., Choi, L., Pohar, B., Jordan, J.,…Biaggioni, I. (2007). Contribution of endothelial nitric oxide to blood pressure in

humans. *Hypertension*, *49*(1), 170-177. https://doi.org/10.1161/01.hyp.0000252425.06216.26

Ghadieh, A. S., & Saab, B. (2015). Evidence for exercise training in the management of hypertension in adults. *Can Fam Physician*, *61*(3), 233-239.

González-Badillo, J. J., & Sánchez-Medina, L. (2010). Movement velocity as a measure of loading intensity in resistance training. *Int J Sports Med*, *31*(5), 347-352. https://doi.org/10.1055/s-0030-1248333

González-Badillo, J. J., Sánchez-Medina, L., Ribas-Serna, J., & Rodríguez-Rosell, D. (2022). Toward a New Paradigm in Resistance Training by Means of Velocity Monitoring: A Critical and Challenging Narrative. *Sports Med Open*, *8*(1), 118. https://doi.org/10.1186/s40798-022-00513-z

González-Badillo, J. J., Yañez-García, J. M., Mora-Custodio, R., & Rodríguez-Rosell, D. (2017). Velocity Loss as a Variable for Monitoring Resistance Exercise. *Int J Sports Med*, *38*(3), 217-225. https://doi.org/10.1055/s-0042-120324

Gorostidi, M., Gijón-Conde, T., De la Sierra, A., Rodilla, E., Rubio, E., Vinyoles, E.,…Molinero, A. (2022). Guía práctica sobre el diagnóstico y tratamiento de la hipertensión arterial en España, 2022. Sociedad Española de Hipertensión-Liga Española para la Lucha contra la Hipertensión Arterial (SEH-LELHA). *Hipertensión y Riesgo Vascular*, *39*(4), 174-194.

Grassi, G., Pisano, A., Bolignano, D., Seravalle, G., D'Arrigo, G., Quarti-Trevano, F.,…Mancia, G. (2018). Sympathetic Nerve Traffic Activation in Essential Hypertension and Its Correlates: Systematic Reviews and Meta-Analyses. *Hypertension*, *72*(2), 483-491. https://doi.org/10.1161/hypertensionaha.118.11038

Gu, C., Yan, J., Zhao, L., Wu, G., & Wang, Y. L. (2021). Regulation of Mitochondrial Dynamics by Aerobic Exercise in Cardiovascular Diseases. *Front Cardiovasc Med*, *8*, 788505. https://doi.org/10.3389/fcvm.2021.788505

Guimaraes, G. V., de Barros Cruz, L. G., Fernandes-Silva, M. M., Dorea, E. L., & Bocchi, E. A. (2014). Heated water-based exercise training reduces 24-hour ambulatory blood pressure levels in resistant hypertensive patients: a randomized controlled trial (HEx trial). *Int J Cardiol*, *172*(2), 434-441. https://doi.org/10.1016/j.ijcard.2014.01.100

Gómez, J. F., Camacho, P. A., López-López, J., & López-Jaramillo, P. (2019). Control y tratamiento de la hipertensión arterial: Programa 20-20. *Revista Colombiana de Cardiología*, *26*(2), 99-106. https://doi.org/https://doi.org/10.1016/j.rccar.2018.06.008

Gómez-Puerto, J. R., Edir Da Silva-Grigoletto, M., Hernán Viana-Montaner, B., Vaamonde, D., & Alvero-Cruz, J. R. (2008). La importancia de los ajustes de la bicicleta en la prevención de las lesiones en el ciclismo: aplicaciones prácticas. *Revista Andaluza de Medicina del Deporte*.

Halling, J. F., & Pilegaard, H. (2020). PGC-1α-mediated regulation of mitochondrial function and physiological implications. *Appl Physiol Nutr Metab*, *45*(9), 927-936. https://doi.org/10.1139/apnm-2020-0005

Halliwill, J. R. (2001). Mechanisms and clinical implications of post-exercise hypotension in humans. *Exerc Sport Sci Rev*, *29*(2), 65-70. https://doi.org/10.1097/00003677-200104000-00005

Halliwill, J. R., Buck, T. M., Lacewell, A. N., & Romero, S. A. (2013). Postexercise hypotension and sustained postexercise vasodilatation: what happens after we exercise? *Exp Physiol*, *98*(1), 7-18. https://doi.org/10.1113/expphysiol.2011.058065

Hansen, D., Abreu, A., Ambrosetti, M., Cornelissen, V., Gevaert, A., Kemps, H.,…Piepoli, M. (2021). Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. *European Journal of Preventive Cardiology*, *29*(1), 230-245. https://doi.org/10.1093/eurjpc/zwab007

Hanssen, H., Boardman, H., Deiseroth, A., Moholdt, T., Simonenko, M., Kränkel, N.,…Leeson, P. (2021). Personalized exercise prescription in the prevention and treatment of arterial hypertension: a Consensus Document from the European Association of Preventive Cardiology (EAPC) and the ESC Council on Hypertension. *Eur J Prev Cardiol*. https://doi.org/10.1093/eurjpc/zwaa141

Hanssen, H., Boardman, H., Deiseroth, A., Moholdt, T., Simonenko, M., Kränkel, N.,…Leeson, P. (2022). Personalized exercise prescription in the prevention and treatment of arterial hypertension: a Consensus Document from the European Association of Preventive Cardiology (EAPC) and the ESC Council on Hypertension. *Eur J Prev Cardiol*, *29*(1), 205-215. https://doi.org/10.1093/eurjpc/zwaa141

Harrison, D. G., Coffman, T. M., & Wilcox, C. S. (2021). Pathophysiology of Hypertension: The Mosaic Theory and Beyond. *Circ Res*, *128*(7), 847-863. https://doi.org/10.1161/circresaha.121.318082

Hejazi, K., Iraj, Z. A., Saeidi, A., Hackney, A. C., Laziri, F., Suzuki, K.,…Hassane, Z. (2025). Differential effects of exercise training protocols on blood pressures and lipid profiles in older adults patients with hypertension: A systematic review and meta-analysis. *Arch Gerontol Geriatr*, *131*, 105737. https://doi.org/10.1016/j.archger.2024.105737

Herrod, P. J. J., Doleman, B., Blackwell, J. E. M., O'Boyle, F., Williams, J. P., Lund, J. N., & Phillips, B. E. (2018). Exercise and other nonpharmacological strategies to reduce blood pressure in older adults: a systematic review and meta-analysis. *J Am Soc Hypertens*, *12*(4), 248-267. https://doi.org/10.1016/j.jash.2018.01.008

Higgins, J. P., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons.

Higgins, J. P., & Thompson, S. G. (2004). Controlling the risk of spurious findings from meta‐regression. *Statistics in medicine*, *23*(11), 1663-1682.

Higgins, J. P. T. (2011). Green, S. (Eds.) Cochrane handbook for systematic reviews of interventions. Version 5.1. 0 [updated March 2011]. The Cochrane Collaboration. *www. cochrane-handbook. org*.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*, *41*(1), 3-13. https://doi.org/10.1249/MSS.0b013e31818cb278

Huai, P., Xun, H., Reilly, K. H., Wang, Y., Ma, W., & Xi, B. (2013). Physical activity and risk of hypertension: a meta-analysis of prospective cohort studies. *Hypertension*, *62*(6), 1021-1026. https://doi.org/10.1161/hypertensionaha.113.01965

Hypertension, E. S. o. (2010). Automated Devices for Clinical Use. Dabl Educational Trust, resting cuff sizes 16-24, 22-32 and 31-45 cm. In.

INE. (2023). Estadística de defunciones según la causa de muerte. *Instituto Nacional de Estadística. España*.

Ito, S. (2019). High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol. *World J Cardiol*, *11*(7), 171-188. https://doi.org/10.4330/wjc.v11.i7.171

Joseph, G., Marott, J. L., Torp-Pedersen, C., Biering-Sørensen, T., Nielsen, G., Christensen, A. E.,…Mogelvang, R. (2019). Dose-Response Association Between Level of Physical Activity and Mortality in Normal, Elevated, and High Blood Pressure. *Hypertension*, *74*(6), 1307-1315. https://doi.org/10.1161/hypertensionaha.119.13786

Jung, S., & Kim, K. (2014). Exercise-induced PGC-1α transcriptional factors in skeletal muscle. *Integrative medicine research*, *3*(4), 155-160.

Kaminsky, L. A., Lavie, C. J., Flint, K., Arena, R., & Bond, S. (2022). Working Toward Optimal Exercise Prescription: Strength Training Should Not Be Overlooked. *J Cardiopulm Rehabil Prev*, *42*(2), E32-e33. https://doi.org/10.1097/hcr.0000000000000696

Kario, K., Okura, A., Hoshide, S., & Mogi, M. (2024). The WHO Global report 2023 on hypertension warning the emerging hypertension burden in globe and its treatment strategy. In *Hypertens Res* (Vol. 47, pp. 1099-1102). © 2024. The Author(s), under exclusive licence to The Japanese Society of Hypertension. https://doi.org/10.1038/s41440-024-01622-w

Karvonen, M. J., Kentala, E., & Mustala, O. (1957). The effects of training on heart rate; a longitudinal study. *Ann Med Exp Biol Fenn*, *35*(3), 307-315.

Katsurada, K., Ogoyama, Y., Imai, Y., Patel, K. P., & Kario, K. (2021). Renal denervation based on experimental rationale. *Hypertens Res*, *44*(11), 1385-1394. https://doi.org/10.1038/s41440-021-00746-7

Kazemi, S. S., Heidarianpour, A., & Shokri, E. (2023). Effect of resistance training and high-intensity interval training on metabolic parameters and serum level of Sirtuin1 in postmenopausal women with metabolic syndrome: a randomized controlled trial. *Lipids Health Dis*, *22*(1), 177. https://doi.org/10.1186/s12944-023-01940-x

Keating, S. E., Johnson, N. A., Mielke, G. I., & Coombes, J. S. (2017). A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity. *Obes Rev*, *18*(8), 943-964. https://doi.org/10.1111/obr.12536

Kemler, E., Noteboom, L., & van Beijsterveldt, A. M. (2022). Characteristics of Fitness-Related Injuries in The Netherlands: A Descriptive Epidemiological Study. *Sports (Basel)*, *10*(12). https://doi.org/10.3390/sports10120187

Khalafi, M., Malandish, A., Rosenkranz, S. K., & Ravasi, A. A. (2021). Effect of resistance training with and without caloric restriction on visceral fat: A

systemic review and meta-analysis. *Obes Rev*, *22*(9), e13275. https://doi.org/10.1111/obr.13275

Khalafi, M., Sakhaei, M. H., Rosenkranz, S. K., & Symonds, M. E. (2022). Impact of concurrent training versus aerobic or resistance training on cardiorespiratory fitness and muscular strength in middle-aged to older adults: A systematic review and meta-analysis. *Physiol Behav*, *254*, 113888. https://doi.org/10.1016/j.physbeh.2022.113888

Khalil, H., & Zelster, R. (2020). Antihypertensive Medications. In.

Konukoglu, D., & Uzun, H. (2017). Endothelial Dysfunction and Hypertension. *Adv Exp Med Biol*, *956*, 511-540. https://doi.org/10.1007/5584_2016_90

Lahav, Y., Goldstein, N., & Gepner, Y. (2021). Comparison of body composition assessment across body mass index categories by two multifrequency bioelectrical impedance analysis devices and dual-energy X-ray absorptiometry in clinical settings. *Eur J Clin Nutr*, *75*(8), 1275-1282. https://doi.org/10.1038/s41430-020-00839-5

Laterza, M. C., de Matos, L. D., Trombetta, I. C., Braga, A. M., Roveda, F., Alves, M. J.,…Rondon, M. U. (2007). Exercise training restores baroreflex sensitivity in never-treated hypertensive patients. *Hypertension*, *49*(6), 1298-1306. https://doi.org/10.1161/hypertensionaha.106.085548

Laurent, S. (2017). Antihypertensive drugs. *Pharmacol Res*, *124*, 116-125. https://doi.org/10.1016/j.phrs.2017.07.026

Lea, J. W. D., O'Driscoll, J. M., Hulbert, S., Scales, J., & Wiles, J. D. (2022). Convergent Validity of Ratings of Perceived Exertion During Resistance Exercise in Healthy Participants: A Systematic Review and Meta-Analysis. In *Sports Med Open* (Vol. 8, pp. 2). © 2022. The Author(s). https://doi.org/10.1186/s40798-021-00386-8

Li, L., Liu, X., Shen, F., Xu, N., Li, Y., Xu, K.,…Liu, Y. (2022). Effects of high-intensity interval training versus moderate-intensity continuous training on blood pressure in patients with hypertension: A meta-analysis. *Medicine (Baltimore)*, *101*(50), e32246. https://doi.org/10.1097/md.0000000000032246

Li, Y., Hanssen, H., Cordes, M., Rossmeissl, A., Endes, S., & Schmidt-Trucksäss, A. (2015). Aerobic, resistance and combined exercise training on arterial stiffness in normotensive and hypertensive adults: A review. *Eur J Sport Sci*, *15*(5), 443-457. https://doi.org/10.1080/17461391.2014.955129

Liguori, G., & Medicine, A. C. o. S. (2020). *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins.

Lim, A. Y., Chen, Y. C., Hsu, C. C., Fu, T. C., & Wang, J. S. (2022). The Effects of Exercise Training on Mitochondrial Function in Cardiovascular Diseases: A Systematic Review and Meta-Analysis. *Int J Mol Sci*, *23*(20). https://doi.org/10.3390/ijms232012559

Lima, L. G., Bonardi, J. T. M., Campos, G. O., Bertani, R. F., Scher, L. M. L., Moriguti, J. C.,…Lima, N. K. C. (2017). Combined aerobic and resistance training: are there additional benefits for older hypertensive adults? *Clinics (Sao Paulo)*, *72*(6), 363-369. https://doi.org/10.6061/clinics/2017(06)06

Liu, X., Zhang, D., Liu, Y., Sun, X., Han, C., Wang, B.,…Zhang, M. (2017). Dose-Response Association Between Physical Activity and Incident

Hypertension: A Systematic Review and Meta-Analysis of Cohort Studies. *Hypertension*, *69*(5), 813-820. https://doi.org/10.1161/hypertensionaha.116.08994

López-Ruiz, I., Lozano, F., Masia, M. D., & González-Gálvez, N. (2023). Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Sports (Basel)*, *11*(6). https://doi.org/10.3390/sports11060115

López-Ruiz, I., Ruiz-Poveda, F. L., Masía, M. D., Heredia-Elvar, J. R., & González-Gálvez, N. (2025). Moderate intensity continuous training, combined moderate-intensity continuous training vs combined high-intensity interval training in adults with hypertension: Randomized controlled trial. *Complementary Therapies in Clinical Practice*, *59*, 101960. https://doi.org/https://doi.org/10.1016/j.ctcp.2025.101960

Magnussen, C., Ojeda, F. M., Leong, D. P., Alegre-Diaz, J., Amouyel, P., Aviles-Santa, L.,…Blankenberg, S. (2023). Global Effect of Modifiable Risk Factors on Cardiovascular Disease and Mortality. *N Engl J Med*, *389*(14), 1273-1285. https://doi.org/10.1056/NEJMoa2206916

Mancia, G., & Grassi, G. (2014). The autonomic nervous system and hypertension. *Circulation research*, *114*(11), 1804-1814.

Mancia, G., Kreutz, R., Brunström, M., Burnier, M., Grassi, G., Januszewicz, A.,…Kjeldsen, S. E. (2023). 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). *J Hypertens*, *41*(12), 1874-2071. https://doi.org/10.1097/hjh.0000000000003480

Marcos-Pardo, P., González-Gálvez, N., Vaquero-Cristóbal, R., Sagarra, L., López-Vivancos, A., Velazquez, D.,…Carbonell-Baeza, A. (2021). Programa de Intervención Multidominio Healthy-Age. Recomendaciones para un envejecimiento saludable: por la red Healthy-Age / Multidomain Healthy-Age Programme. Recomendations for Healthy Ageing: On Behalf of the Healthy-Age Network. *Cultura, Ciencia y Deporte*, *16*, 311-320. https://doi.org/10.12800/ccd.v16i48.1743

Marcos-Pardo, P. J., González-Hernández, J. M., García-Ramos, A., López-Vivancos, A., & Jiménez-Reyes, P. (2019). Movement velocity can be used to estimate the relative load during the bench press and leg press exercises in older women. *PeerJ*, *7*, e7533. https://doi.org/10.7717/peerj.7533

Marfell Jones, M., Olds, T., Stewart, A., & Carter, L. (2006). Sociedad Internacional para el Avance de la Cineantropometría (ISAK). *Manual ISAK*.

Marqueta, P. M., Bonafonte, L. F., Orellana, J. N., Cuixart, D. B., Nogués, J. C., Soto, C. C.,…Canales, M. G. (2016). Pruebas de esfuerzo en medicina del deporte. Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE). *Archivos de medicina del deporte: revista de la Federación Española de Medicina del Deporte y de la Confederación Iberoamericana de Medicina del Deporte*, *33*(1), 5-83.

Masroor, S., Bhati, P., Verma, S., Khan, M., & Hussain, M. E. (2018). Heart Rate Variability following Combined Aerobic and Resistance Training in Sedentary Hypertensive Women: A Randomised Control Trial. *Indian Heart J, 70 Suppl 3*(Suppl 3), S28-s35. https://doi.org/10.1016/j.ihj.2018.03.005

Mathiowetz, V., Kashman, N., Volland, G., Weber, K., Dowe, M., & Rogers, S. (1985). Grip and pinch strength: normative data for adults. *Arch Phys Med Rehabil*, *66*(2), 69-74.

McClean, Z. J., Pasanen, K., Lun, V., Charest, J., Herzog, W., Werthner, P.,…Jordan, M. J. (2024). A Biopsychosocial Model for Understanding Training Load, Fatigue, and Musculoskeletal Sport Injury in University Athletes: A Scoping Review. *J Strength Cond Res*, *38*(6), 1177-1188. https://doi.org/10.1519/jsc.0000000000004789

McEvoy, J. W., McCarthy, C. P., Bruno, R. M., Brouwers, S., Canavan, M. D., Ceconi, C.,…Touyz, R. M. (2024). 2024 ESC Guidelines for the management of elevated blood pressure and hypertension. *Eur Heart J*, *45*(38), 3912-4018. https://doi.org/10.1093/eurheartj/ehae178

McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. *Sports Med*, *45*(11), 1523-1546. https://doi.org/10.1007/s40279-015-0376-x

McGregor, G., Powell, R., Begg, B., Birkett, S. T., Nichols, S., Ennis, S.,…Shave, R. (2023). High-intensity interval training in cardiac rehabilitation: a multi-centre randomized controlled trial. *Eur J Prev Cardiol*, *30*(9), 745-755. https://doi.org/10.1093/eurjpc/zwad039

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*, *22*(3), 276-282.

Mensah, G. A., Fuster, V., Murray, C. J. L., & Roth, G. A. (2023). Global Burden of Cardiovascular Diseases and Risks, 1990-2022. *J Am Coll Cardiol*, *82*(25), 2350-2473. https://doi.org/10.1016/j.jacc.2023.11.007

Menéndez, E., Delgado, E., Fernández-Vega, F., Prieto, M. A., Bordiú, E., Calle, A.,…Soriguer, F. (2016). Prevalence, Diagnosis, Treatment, and Control of Hypertension in Spain. Results of the Di@bet.es Study. *Rev Esp Cardiol (Engl Ed)*, *69*(6), 572-578. https://doi.org/10.1016/j.rec.2015.11.034

Mitchell, B. L., Davison, K., Parfitt, G., Spedding, S., & Eston, R. G. (2019). Physiological and Perceived Exertion Responses during Exercise: Effect of β-blockade. *Med Sci Sports Exerc*, *51*(4), 782-791. https://doi.org/10.1249/mss.0000000000001845

Momma, H., Kawakami, R., Honda, T., & Sawada, S. S. (2022). Muscle-strengthening activities are associated with lower risk and mortality in major non-communicable diseases: a systematic review and meta-analysis of cohort studies. *Br J Sports Med*, *56*(13), 755-763. https://doi.org/10.1136/bjsports-2021-105061

Morán-Navarro, R., Martínez-Cava, A., Sánchez-Medina, L., Mora-Rodríguez, R., González-Badillo, J. J., & Pallarés, J. G. (2019). Movement Velocity as a Measure of Level of Effort During Resistance Exercise. *J Strength Cond Res*, *33*(6), 1496-1504. https://doi.org/10.1519/jsc.0000000000002017

Motlagh, J. G., & Lipps, D. B. (2024). The Contribution of Muscular Fatigue and Shoulder Biomechanics to Shoulder Injury Incidence During the Bench Press Exercise: A Narrative Review. *J Strength Cond Res*, *38*(12), 2147-2163. https://doi.org/10.1519/jsc.0000000000004973

Mul, J. D., Stanford, K. I., Hirshman, M. F., & Goodyear, L. J. (2015). Exercise and Regulation of Carbohydrate Metabolism. *Prog Mol Biol Transl Sci*, *135*, 17-37. https://doi.org/10.1016/bs.pmbts.2015.07.020

Murray, C. J. L., Aravkin, A. Y., Zheng, P., Abbafati, C., Abbas, K. M., Abbasi-Kangevari, M.,…Lim, S. S. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10258), 1223-1249. https://doi.org/10.1016/S0140-6736(20)30752-2

Mølmen, K. S., Almquist, N. W., & Skattebo, Ø. (2025). Effects of Exercise Training on Mitochondrial and Capillary Growth in Human Skeletal Muscle: A Systematic Review and Meta-Regression. *Sports Med*, *55*(1), 115-144. https://doi.org/10.1007/s40279-024-02120-2

Nayor, M., Gajjar, P., Murthy, V. L., Miller, P. E., Velagaleti, R. S., Larson, M. G.,…Shah, R. V. (2023). Blood Pressure Responses During Exercise: Physiological Correlates and Clinical Implications. *Arterioscler Thromb Vasc Biol*, *43*(1), 163-173. https://doi.org/10.1161/atvbaha.122.318512

Nazir, A., Heryaman, H., Juli, C., Ugusman, A., Martha, J. W., Moeliono, M. A., & Atik, N. (2024). Resistance Training in Cardiovascular Diseases: A Review on Its Effectiveness in Controlling Risk Factors. *Integr Blood Press Control*, *17*, 21-37. https://doi.org/10.2147/ibpc.s449086

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C.,…Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*, *39*(8), 1435-1445. https://doi.org/10.1249/mss.0b013e3180616aa2

NICE. (2023). National Institute for Health and Care Excellence: Guidelines. In *Hypertension in adults: diagnosis and management*. National Institute for Health and Care Excellence (NICE)

Copyright © NICE 2023.

Node, K., Kitakaze, M., Yoshikawa, H., Kosaka, H., & Hori, M. (1997). Reduced plasma concentrations of nitrogen oxide in individuals with essential hypertension. *Hypertension*, *30*(3 Pt 1), 405-408. https://doi.org/10.1161/01.hyp.30.3.405

Organization, W. H. (1989). Study group on diet, nutrition and prevention of noncommunicable diseases. *Diet, Nutrition and the Prevention of Chronic Disease: Report of a World Health Organization Study Group*.

Organization, W. H. (2023). Global report on hypertension: The race against a silent killer.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D.,…Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, *372*, n71. https://doi.org/10.1136/bmj.n71

Paluch, A. E., Boyer, W. R., Franklin, B. A., Laddu, D., Lobelo, F., Lee, D. C.,…Lane, A. (2024). Resistance Exercise Training in Individuals With and Without Cardiovascular Disease: 2023 Update: A Scientific Statement From the American Heart Association. *Circulation*, *149*(3), e217-e231. https://doi.org/10.1161/cir.0000000000001189

Pantell, M. S., Prather, A. A., Downing, J. M., Gordon, N. P., & Adler, N. E. (2019). Association of Social and Behavioral Risk Factors With Earlier Onset of Adult Hypertension and Diabetes. *JAMA Netw Open*, *2*(5), e193933. https://doi.org/10.1001/jamanetworkopen.2019.3933

Pareja-Blanco, F., Rodríguez-Rosell, D., Sánchez-Medina, L., Sanchis-Moysi, J., Dorado, C., Mora-Custodio, R.,…González-Badillo, J. J. (2017). Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations. *Scand J Med Sci Sports*, *27*(7), 724-735. https://doi.org/10.1111/sms.12678

Pareja-Blanco, F., Sánchez-Medina, L., Suárez-Arrones, L., & González-Badillo, J. J. (2017). Effects of Velocity Loss During Resistance Training on Performance in Professional Soccer Players. *Int J Sports Physiol Perform*, *12*(4), 512-519. https://doi.org/10.1123/ijspp.2016-0170

Patel, K. P., Katsurada, K., & Zheng, H. (2022). Cardiorenal Syndrome: The Role of Neural Connections Between the Heart and the Kidneys. *Circ Res*, *130*(10), 1601-1617. https://doi.org/10.1161/circresaha.122.319989

Pedersen, B. K. (2006). The anti-inflammatory effect of exercise: its role in diabetes and cardiovascular disease control. *Essays Biochem*, *42*, 105-117. https://doi.org/10.1042/bse0420105

Pedersen, B. K., & Febbraio, M. A. (2008). Muscle as an endocrine organ: focus on muscle-derived interleukin-6. *Physiol Rev*, *88*(4), 1379-1406. https://doi.org/10.1152/physrev.90100.2007

Pedersen, B. K., & Febbraio, M. A. (2012). Muscles, exercise and obesity: skeletal muscle as a secretory organ. *Nat Rev Endocrinol*, *8*(8), 457-465. https://doi.org/10.1038/nrendo.2012.49

Pedersen, B. K., & Saltin, B. (2015). Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scand J Med Sci Sports*, *25 Suppl 3*, 1-72. https://doi.org/10.1111/sms.12581

Pelliccia, A., Sharma, S., Gati, S., Bäck, M., Börjesson, M., Caselli, S.,…Group, E. S. D. (2020). 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease: The Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). *European Heart Journal*, *42*(1), 17-96. https://doi.org/10.1093/eurheartj/ehaa605

Perry, A. S., Dooley, E. E., Master, H., Spartano, N. L., Brittain, E. L., & Pettee Gabriel, K. (2023). Physical Activity Over the Lifecourse and Cardiovascular Disease. *Circ Res*, *132*(12), 1725-1740. https://doi.org/10.1161/circresaha.123.322121

Pescatello, L. S. (2020). What's New in the ACSM Pronouncement on Exercise and Hypertension. *Medicine ACoS, ed. American College of Sport Medicine Blog.*

Pescatello, L. S., Buchner, D. M., Jakicic, J. M., Powell, K. E., Kraus, W. E., Bloodgood, B.,…Piercy, K. L. (2019). Physical Activity to Prevent and Treat Hypertension: A Systematic Review. *Med Sci Sports Exerc*, *51*(6), 1314-1323. https://doi.org/10.1249/mss.0000000000001943

Pescatello, L. S., Franklin, B. A., Fagard, R., Farquhar, W. B., Kelley, G. A., & Ray, C. A. (2004). American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc*, *36*(3), 533-553. https://doi.org/10.1249/01.mss.0000115224.88514.3a

Pescatello, L. S., MacDonald, H. V., Lamberti, L., & Johnson, B. T. (2015). Exercise for Hypertension: A Prescription Update Integrating Existing Recommendations with Emerging Research. *Curr Hypertens Rep*, *17*(11), 87. https://doi.org/10.1007/s11906-015-0600-y

Pesova, P., Jiravska Godula, B., Jiravsky, O., Jelinek, L., Sovova, M., Moravcova, K.,…Sovova, E. (2023). Exercise-Induced Blood Pressure Dynamics: Insights from the General Population and the Athletic Cohort. *J Cardiovasc Dev Dis*, *10*(12). https://doi.org/10.3390/jcdd10120480

Pito, P. G., Cardoso, J. R., Tufano, J., & Guariglia, D. (2022). Effects of Concurrent Training on 1RM and VO2 in Adults: Systematic Review with Meta-analysis. *Int J Sports Med*, *43*(4), 297-304. https://doi.org/10.1055/a-1506-3007

Poli, L., Petrelli, A., Fischetti, F., Morsanuto, S., Talaba, L., Cataldi, S., & Greco, G. (2025). The Effects of Multicomponent Training on Clinical, Functional, and Psychological Outcomes in Cardiovascular Disease: A Narrative Review. *Medicina (Kaunas)*, *61*(5). https://doi.org/10.3390/medicina61050822

Poon, E. T., Li, H. Y., Little, J. P., Wong, S. H., & Ho, R. S. (2024). Efficacy of Interval Training in Improving Body Composition and Adiposity in Apparently Healthy Adults: An Umbrella Review with Meta-Analysis. *Sports Med*, *54*(11), 2817-2840. https://doi.org/10.1007/s40279-024-02070-9

Rabi, D. M., McBrien, K. A., Sapir-Pichhadze, R., Nakhla, M., Ahmed, S. B., Dumanski, S. M.,…Daskalopoulou, S. S. (2020). Hypertension Canada's 2020 Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children. *Can J Cardiol*, *36*(5), 596-624. https://doi.org/10.1016/j.cjca.2020.02.086

Ramos, J. S., Dalleck, L. C., Tjonna, A. E., Beetham, K. S., & Coombes, J. S. (2015). The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: a systematic review and meta-analysis. *Sports Med*, *45*(5), 679-692. https://doi.org/10.1007/s40279-015-0321-z

Razo, C., Welgan, C. A., Johnson, C. O., McLaughlin, S. A., Iannucci, V., Rodgers, A.,…Roth, G. A. (2022). Effects of elevated systolic blood pressure on ischemic heart disease: a Burden of Proof study. *Nat Med*, *28*(10), 2056-2065. https://doi.org/10.1038/s41591-022-01974-1

Riddell, M. C., Gallen, I. W., Smart, C. E., Taplin, C. E., Adolfsson, P., Lumb, A. N.,…Laffel, L. M. (2017). Exercise management in type 1 diabetes: a consensus statement. *Lancet Diabetes Endocrinol*, *5*(5), 377-390. https://doi.org/10.1016/s2213-8587(17)30014-1

Rijal, A., Adhikari, T. B., Dhakal, S., Maagaard, M., Piri, R., Nielsen, E. E.,…Olsen, M. H. (2024). Effects of adding exercise to usual care on blood pressure in patients with hypertension, type 2 diabetes, or cardiovascular disease: a systematic review with meta-analysis and trial sequential analysis. *J Hypertens*, *42*(1), 10-22. https://doi.org/10.1097/hjh.0000000000003589

Rimoldi, S. F., Scherrer, U., & Messerli, F. H. (2014). Secondary arterial hypertension: when, who, and how to screen? *Eur Heart J*, *35*(19), 1245-1254. https://doi.org/10.1093/eurheartj/eht534

Robertson, R. J., Goss, F. L., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J.,…Andreacci, J. (2003). Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc*, *35*(2), 333-341. https://doi.org/10.1249/01.mss.0000048831.15016.2a

Rodríguez-Rosell, D., Yáñez-García, J. M., Mora-Custodio, R., Pareja-Blanco, F., Ravelo-García, A. G., Ribas-Serna, J., & González-Badillo, J. J. (2020). Velocity-based resistance training: impact of velocity loss in the set on neuromuscular performance and hormonal response. *Appl Physiol Nutr Metab*, *45*(8), 817-828. https://doi.org/10.1139/apnm-2019-0829

Rodríguez-Rosell, D., Yáñez-García, J. M., Mora-Custodio, R., Sánchez-Medina, L., Ribas-Serna, J., & González-Badillo, J. J. (2021). Effect of velocity loss during squat training on neuromuscular performance. *Scand J Med Sci Sports*, *31*(8), 1621-1635. https://doi.org/10.1111/sms.13967

Rodríguez-Rosell, D., Yáñez-García, J. M., Mora-Custodio, R., Torres-Torrelo, J., Ribas-Serna, J., & González-Badillo, J. J. (2020). Role of the Effort Index in Predicting Neuromuscular Fatigue During Resistance Exercises. *J Strength Cond Res*. https://doi.org/10.1519/jsc.0000000000003805

Rodríguez-Rosell, D., Yáñez-García, J. M., Sánchez-Medina, L., Mora-Custodio, R., & González-Badillo, J. J. (2020). Relationship between velocity loss and repetitions in reserve in the bench press and back squat exercises. *The Journal of Strength & Conditioning Research*, *34*(9), 2537-2547.

Rodríguez-Rosell, D., Yáñez-García, J. M., Torres-Torrelo, J., Mora-Custodio, R., Marques, M. C., & González-Badillo, J. J. (2018). Effort index as a novel variable for monitoring the level of effort during resistance exercises. *The Journal of Strength & Conditioning Research*, *32*(8), 2139-2153.

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin*, *86*, 638-641.

Rossi, F. E., Fortaleza, A. C., Neves, L. M., Buonani, C., Picolo, M. R., Diniz, T. A.,…Freitas Junior, I. F. (2016). Combined Training (Aerobic Plus Strength) Potentiates a Reduction in Body Fat but Demonstrates No Difference on the Lipid Profile in Postmenopausal Women When Compared With Aerobic Training With a Similar Training Load. *J Strength Cond Res*, *30*(1), 226-234. https://doi.org/10.1519/jsc.0000000000001020

Roth, G. A., Abate, D., Abate, K. H., Abay, S. M., Abbafati, C., Abbasi, N.,…al, e. (2018). Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*, *392*(10159), 1736-1788. https://doi.org/10.1016/s0140-6736(18)32203-7

Sabbahi, A., Arena, R., Kaminsky, L. A., Myers, J., & Phillips, S. A. (2018). Peak Blood Pressure Responses During Maximum Cardiopulmonary Exercise Testing: Reference Standards From FRIEND (Fitness Registry and the Importance of Exercise: A National Database). *Hypertension*, *71*(2), 229-236. https://doi.org/10.1161/hypertensionaha.117.10116

Saco-Ledo, G., Valenzuela, P. L., Ruilope, L. M., & Lucia, A. (2022). Physical Exercise in Resistant Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Front Cardiovasc Med*, *9*, 893811. https://doi.org/10.3389/fcvm.2022.893811

Sadler, S. G., Spink, M. J., Ho, A., De Jonge, X. J., & Chuter, V. H. (2017). Restriction in lateral bending range of motion, lumbar lordosis, and hamstring flexibility predicts the development of low back pain: a systematic review of prospective cohort studies. *BMC Musculoskelet Disord*, *18*(1), 179. https://doi.org/10.1186/s12891-017-1534-0

Safran, M. R., Seaber, A. V., & Garrett, W. E., Jr. (1989). Warm-up and muscular injury prevention. An update. *Sports Med*, *8*(4), 239-249. https://doi.org/10.2165/00007256-198908040-00004

Sale, D. G. (1988). Neural adaptation to resistance training. *Medicine and science in sports and exercise*, *20*(5 Suppl), S135-145.

Sale, D. G. (1988). Neural adaptation to resistance training. *Med Sci Sports Exerc*, *20*(5 Suppl), S135-145. https://doi.org/10.1249/00005768-198810001-00009

San-Millan, I., Martinez, J., Sparagna, G., D'Alessandro, A., Stefanoni, D., Nemkov, T., & Hill, J. (2024). Metabolic and Cellular Differences Between Sedentary and Active Individuals at Rest and During Exercise. *bioRxiv*, 2024.2008. 2019.608601.

San-Millán, I. (2021). Assessing metabolic flexibility and mitochondrial bioenergetics. In *Clinical Bioenergetics* (pp. 245-268). Elsevier.

San-Millán, I. (2023). The key role of mitochondrial function in health and disease. *Antioxidants*, *12*(4), 782.

Schneider, V. M., Domingues, L. B., Umpierre, D., Tanaka, H., & Ferrari, R. (2023). Exercise characteristics and blood pressure reduction after combined aerobic and resistance training: a systematic review with meta-analysis and meta-regression. *J Hypertens*, *41*(7), 1068-1076. https://doi.org/10.1097/hjh.0000000000003455

Schoenfeld, B. J., Grgic, J., Van Every, D. W., & Plotkin, D. L. (2021). Loading Recommendations for Muscle Strength, Hypertrophy, and Local Endurance: A Re-Examination of the Repetition Continuum. *Sports (Basel)*, *9*(2). https://doi.org/10.3390/sports9020032

Schroeder, E. C., Franke, W. D., Sharp, R. L., & Lee, D. C. (2019). Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PLoS One*, *14*(1), e0210292. https://doi.org/10.1371/journal.pone.0210292

Schulz, E., Gori, T., & Münzel, T. (2011). Oxidative stress and endothelial dysfunction in hypertension. *Hypertens Res*, *34*(6), 665-673. https://doi.org/10.1038/hr.2011.39

Schumann, M., Feuerbacher, J. F., Sünkeler, M., Freitag, N., Rønnestad, B. R., Doma, K., & Lundberg, T. R. (2022). Compatibility of Concurrent Aerobic and Strength Training for Skeletal Muscle Size and Function: An Updated Systematic Review and Meta-Analysis. *Sports Med*, *52*(3), 601-612. https://doi.org/10.1007/s40279-021-01587-7

Seeley, A. D., Giersch, G. E. W., & Charkoudian, N. (2021). Post-exercise Body Cooling: Skin Blood Flow, Venous Pooling, and Orthostatic Intolerance. *Front Sports Act Living*, *3*, 658410. https://doi.org/10.3389/fspor.2021.658410

Severinsen, M. C. K., & Pedersen, B. K. (2020). Muscle-Organ Crosstalk: The Emerging Roles of Myokines. *Endocr Rev*, *41*(4), 594-609. https://doi.org/10.1210/endrev/bnaa016

Shenouda, N., Gillen, J. B., Gibala, M. J., & MacDonald, M. J. (2017). Changes in brachial artery endothelial function and resting diameter with moderate-intensity continuous but not sprint interval training in sedentary men. *J Appl Physiol (1985)*, *123*(4), 773-780. https://doi.org/10.1152/japplphysiol.00058.2017

Silva, J., Menêses, A. L., Parmenter, B. J., Ritti-Dias, R. M., & Farah, B. Q. (2021). Effects of resistance training on endothelial function: A systematic review and meta-analysis. *Atherosclerosis*, *333*, 91-99. https://doi.org/10.1016/j.atherosclerosis.2021.07.009

Son, W. M., Sung, K. D., Cho, J. M., & Park, S. Y. (2016). Combined exercise reduces arterial stiffness, blood pressure, and blood markers for cardiovascular risk in postmenopausal women with hypertension. *Menopause*, *24*(3), 262-268. https://doi.org/10.1097/gme.0000000000000765

Sousa, N., Mendes, R., Abrantes, C., Sampaio, J., & Oliveira, J. (2013). A randomized 9-month study of blood pressure and body fat responses to aerobic training versus combined aerobic and resistance training in older men. *Exp Gerontol*, *48*(8), 727-733. https://doi.org/10.1016/j.exger.2013.04.008

Spence, A. L., Carter, H. H., Naylor, L. H., & Green, D. J. (2013). A prospective randomized longitudinal study involving 6 months of endurance or resistance exercise. Conduit artery adaptation in humans. *J Physiol*, *591*(5), 1265-1275. https://doi.org/10.1113/jphysiol.2012.247387

Spiering, B. A., Kraemer, W. J., Anderson, J. M., Armstrong, L. E., Nindl, B. C., Volek, J. S., & Maresh, C. M. (2008). Resistance exercise biology: manipulation of resistance exercise programme variables determines the responses of cellular and molecular signalling pathways. *Sports Med*, *38*(7), 527-540. https://doi.org/10.2165/00007256-200838070-00001

Stanaway, J. D., Afshin, A., Gakidou, E., Lim, S. S., Abate, D., Abate, K. H.,…Murray, C. J. L. (2018). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, *392*(10159), 1923-1994. https://doi.org/https://doi.org/10.1016/S0140-6736(18)32225-6

Stergiou, G. S., Palatini, P., Parati, G., O'Brien, E., Januszewicz, A., Lurbe, E.,…Kreutz, R. (2021). 2021 European Society of Hypertension practice

guidelines for office and out-of-office blood pressure measurement. *J Hypertens*, *39*(7), 1293-1302. https://doi.org/10.1097/hjh.0000000000002843

Sterne, J. A., Sutton, A. J., Ioannidis, J. P., Terrin, N., Jones, D. R., Lau, J.,…Higgins, J. P. (2011). Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *Bmj*, *343*, d4002. https://doi.org/10.1136/bmj.d4002

Stewart, K. J., Bacher, A. C., Turner, K. L., Fleg, J. L., Hees, P. S., Shapiro, E. P.,…Ouyang, P. (2005). Effect of exercise on blood pressure in older persons: a randomized controlled trial. *Arch Intern Med*, *165*(7), 756-762. https://doi.org/10.1001/archinte.165.7.756

Strain, T., Flaxman, S., Guthold, R., Semenova, E., Cowan, M., Riley, L. M.,…Stevens, G. A. (2024). National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5·7 million participants. *Lancet Glob Health*, *12*(8), e1232-e1243. https://doi.org/10.1016/s2214-109x(24)00150-5

SÁNCHEZ-MEDINA, L., & GONZÁLEZ-BADILLO, J. J. (2011). Velocity Loss as an Indicator of Neuromuscular Fatigue during Resistance Training. *Medicine & Science in Sports & Exercise*, *43*(9), 1725-1734. https://doi.org/10.1249/MSS.0b013e318213f880

Sánchez-Medina, L., Pallarés, J. G., Pérez, C. E., Morán-Navarro, R., & González-Badillo, J. J. (2017). Estimation of relative load from bar velocity in the full back squat exercise. *Sports medicine international open*, *1*(02), E80-E88.

Taipale, R. S., & Häkkinen, K. (2013). Acute hormonal and force responses to combined strength and endurance loadings in men and women: the "order effect". *PLoS One*, *8*(2), e55051. https://doi.org/10.1371/journal.pone.0055051

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, *37*(1), 153-156. https://doi.org/10.1016/s0735-1097(00)01054-8

Tao, X., Chen, Y., Zhen, K., Ren, S., Lv, Y., & Yu, L. (2023). Effect of continuous aerobic exercise on endothelial function: A systematic review and meta-analysis of randomized controlled trials. In *Front Physiol* (Vol. 14, pp. 1043108). Copyright © 2023 Tao, Chen, Zhen, Ren, Lv and Yu. https://doi.org/10.3389/fphys.2023.1043108

Taylor, J. L., Holland, D. J., Spathis, J. G., Beetham, K. S., Wisløff, U., Keating, S. E., & Coombes, J. S. (2019). Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. *Prog Cardiovasc Dis*, *62*(2), 140-146. https://doi.org/10.1016/j.pcad.2019.01.004

Tian, D., & Meng, J. (2019). Exercise for Prevention and Relief of Cardiovascular Disease: Prognoses, Mechanisms, and Approaches. *Oxid Med Cell Longev*, *2019*, 3756750. https://doi.org/10.1155/2019/3756750

Trevizani, G. A., Seixas, M. B., Benchimol-Barbosa, P. R., Vianna, J. M., da Silva, L. P., & Nadal, J. (2018). Effect of Resistance Training on Blood Pressure and Autonomic Responses in Treated Hypertensives. *J Strength Cond Res*, *32*(5), 1462-1470. https://doi.org/10.1519/jsc.0000000000001995

Unger, T., Borghi, C., Charchar, F., Khan, N. A., Poulter, N. R., Prabhakaran, D.,…Schutte, A. E. (2020). 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension*, *75*(6), 1334-1357. https://doi.org/doi:10.1161/HYPERTENSIONAHA.120.15026

Vaduganathan, M., Mensah, G. A., Turco, J. V., Fuster, V., & Roth, G. A. (2022). The Global Burden of Cardiovascular Diseases and Risk: A Compass for Future Health. *J Am Coll Cardiol*, *80*(25), 2361-2371. https://doi.org/10.1016/j.jacc.2022.11.005

Valenzuela, P. L., Ruilope, L. M., Santos-Lozano, A., Wilhelm, M., Kränkel, N., Fiuza-Luces, C., & Lucia, A. (2023). Exercise benefits in cardiovascular diseases: from mechanisms to clinical implementation. *European Heart Journal*. https://doi.org/10.1093/eurheartj/ehad170

Vallance, P., Collier, J., & Moncada, S. (1989). Effects of endothelium-derived nitric oxide on peripheral arteriolar tone in man. *Lancet*, *2*(8670), 997-1000. https://doi.org/10.1016/s0140-6736(89)91013-1

Visseren, F. L. J., Mach, F., Smulders, Y. M., Carballo, D., Koskinas, K. C., Bäck, M.,…Group, E. S. D. (2021). 2021 ESC Guidelines on cardiovascular disease prevention in clinical practice: Developed by the Task Force for cardiovascular disease prevention in clinical practice with representatives of the European Society of Cardiology and 12 medical societies With the special contribution of the European Association of Preventive Cardiology (EAPC). *European Journal of Preventive Cardiology*, *29*(1), 5-115. https://doi.org/10.1093/eurjpc/zwab154

Warburton, D. E., McKenzie, D. C., Haykowsky, M. J., Taylor, A., Shoemaker, P., Ignaszewski, A. P., & Chan, S. Y. (2005). Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease. *Am J Cardiol*, *95*(9), 1080-1084. https://doi.org/10.1016/j.amjcard.2004.12.063

Watanabe, T., Barker, T. A., & Berk, B. C. (2005). Angiotensin II and the endothelium: diverse signals and effects. *Hypertension*, *45*(2), 163-169. https://doi.org/10.1161/01.HYP.0000153321.13792.b9

Way, K. L., Hackett, D. A., Baker, M. K., & Johnson, N. A. (2016). The Effect of Regular Exercise on Insulin Sensitivity in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis. *Diabetes Metab J*, *40*(4), 253-271. https://doi.org/10.4093/dmj.2016.40.4.253

Way, K. L., Sultana, R. N., Sabag, A., Baker, M. K., & Johnson, N. A. (2019). The effect of high Intensity interval training versus moderate intensity continuous training on arterial stiffness and 24h blood pressure responses: A systematic review and meta-analysis. *J Sci Med Sport*, *22*(4), 385-391. https://doi.org/10.1016/j.jsams.2018.09.228

Wewege, M., van den Berg, R., Ward, R. E., & Keech, A. (2017). The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis. *Obes Rev*, *18*(6), 635-646. https://doi.org/10.1111/obr.12532

Wewege, M. A., Desai, I., Honey, C., Coorie, B., Jones, M. D., Clifford, B. K.,…Hagstrom, A. D. (2022). The Effect of Resistance Training in Healthy

Adults on Body Fat Percentage, Fat Mass and Visceral Fat: A Systematic Review and Meta-Analysis. In *Sports Med* (Vol. 52, pp. 287-300). © 2021. The Author(s), under exclusive licence to Springer Nature Switzerland AG. https://doi.org/10.1007/s40279-021-01562-2

Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Jr., Collins, K. J., Dennison Himmelfarb, C.,…Wright, J. T., Jr. (2018a). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*, *71*(6), 1269-1324. https://doi.org/10.1161/hyp.0000000000000066

Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Jr., Collins, K. J., Dennison Himmelfarb, C.,…Wright, J. T., Jr. (2018b). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*, *138*(17), e426-e483. https://doi.org/10.1161/cir.0000000000000597

WHO. (2023). *Global report on hypertension: the race against a silent killer*. World Health Organization.

Williams, B., Mancia, G., Spiering, W., Agabiti Rosei, E., Azizi, M., Burnier, M.,…Group, E. S. D. (2018). 2018 ESC/ESH Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH). *European Heart Journal*, *39*(33), 3021-3104. https://doi.org/10.1093/eurheartj/ehy339

Williams, M. A., Haskell, W. L., Ades, P. A., Amsterdam, E. A., Bittner, V., Franklin, B. A.,…Stewart, K. J. (2007). Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*, *116*(5), 572-584. https://doi.org/10.1161/circulationaha.107.185214

Woods, K., Bishop, P., & Jones, E. (2007). Warm-up and stretching in the prevention of muscular injury. *Sports Med*, *37*(12), 1089-1099. https://doi.org/10.2165/00007256-200737120-00006

You, Q., Yu, L., Li, G., He, H., & Lv, Y. (2021). Effects of Different Intensities and Durations of Aerobic Exercise on Vascular Endothelial Function in Middle-Aged and Elderly People: A Meta-analysis. *Front Physiol*, *12*, 803102. https://doi.org/10.3389/fphys.2021.803102

Yue, T., Wang, Y., Liu, H., Kong, Z., & Qi, F. (2022). Effects of High-Intensity Interval vs. Moderate-Intensity Continuous Training on Cardiac Rehabilitation in Patients With Cardiovascular Disease: A Systematic Review and Meta-Analysis. *Front Cardiovasc Med*, *9*, 845225. https://doi.org/10.3389/fcvm.2022.845225

Zaleski, A. (2019). Exercise for the Prevention and Treatment of Hypertension– Implications and Application. *American College of Sports Medicine*.

Zhang, Y., Zhang, Y. J., Zhang, H. W., Ye, W. B., & Korivi, M. (2021). Low-to-Moderate-Intensity Resistance Exercise Is More Effective than High-Intensity at Improving Endothelial Function in Adults: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*, *18*(13). https://doi.org/10.3390/ijerph18136723

XI – ANEXOS

XI - ANEXOS

ANEXO 1. Aprovación del Comité de Ética

UCAM
UNIVERSIDAD CATÓLICA SAN ANTONIO

COMITÉ DE ÉTICA DE LA UCAM

DATOS DEL PROYECTO

Título:	"Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria"

Investigador Principal	**Nombre**	**Correo-e**
Dra.	Noelia González Gálvez	ngonzalez@ucam.edu

INFORME DEL COMITÉ

Fecha	**25/06/2021**	**Código**	**CE062107**

Tipo de Experimentación

Investigación experimental clínica con seres humanos	X
Investigación experimental no clínica con seres humanos	
Utilización de tejidos humanos procedentes de pacientes, personas sanas, tejidos embrionarios o fetales	X
Utilización de tejidos humanos, tejidos embrionarios o fetales procedentes de bancos de muestras o tejidos	
Investigación observacional, psicológica o comportamental en humanos	
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

UNIVERSIDAD CATOLICA SAN ANTONIO · COMITE DE ETICA ·

Universidad Católica San Antonio. Vicerrectorado de Investigación. Salida nº 7865 25/06/2021 18:29:56

UCAM
UNIVERSIDAD CATÓLICA SAN ANTONIO

COMITÉ DE ÉTICA DE LA UCAM

Sugerencias al Investigador

A la vista de la solicitud de informe adjunto por el Investigador y de las recomendaciones anteriormente expuestas el dictamen del Comité es:

Emitir Informe Favorable	**X**
Emitir Informe Desfavorable	
Emitir Informe Favorable condicionado a Subsanación	
MOTIVACIÓN	
Incrementará conocimientos en su área	

Vº Bº El Presidente,

Fdo.: José Alberto Cánovas Sánchez

El Secretario,

UNIVERSIDAD CATÓLICA SAN ANTONIO · COMITÉ DE ÉTICA ·

Fdo.: José Alarcón Teruel

ANEXO 2. Aprobación definitiva del CEIM

Gerencia Atención Integrada — Ciudad Real

sescam

INFORME DEL COMITÉ DE ÉTICA DE INVESTIGACIÓN CON MEDICAMENTOS

El Comité de Ética de Investigación con medicamentos de la Gerencia de Atención Integrada de Ciudad Real, en su reunión del día 19/07/2022 (Acta nº 07/2022),

Acordó la:

°° **APROBACIÓN DEFINITIVA**

Del estudio descrito a continuación:

Título: **"Efectos del Entrenamiento Multicomponente frente al Entrenamiento Selectivo Cardiovascular como Tratamiento Coadyuvante en el control y tratamiento de la Hipertensión Arterial en sujetos Adultos desde la Atención Primaria".**
Código interno: C-557
Protocolo: Fecha 15/05/2021
HIP/CI: Fecha 13/12/2021
Investigador principal y Doctoranda: Isabel María López Ruiz.
Directores: Noelia González Gálvez, Fernando Lozano Ruiz-Poveda y José Abellán Huerta.

sescam
COMITÉ DE ÉTICA DE INVESTIGACIÓN CON MEDICAMENTOS

En Ciudad Real, a 19 de julio de 2022

Fdo.: Pilar Vicente Sánchez
Presidente CEIm

HOSPITAL GENERAL UNIVERSITARIO
CEIm
c/ Obispo Rafael Torija, s/n
13005 Ciudad Real (España)

Gerencia Atención Integrada Ciudad Real

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INFORME DEL COMITÉ DE ÉTICA DE INVESTIGACIÓN CON MEDICAMENTOS

Dª. PILAR VICENTE SÁNCHEZ, Presidente del Comité de Ética de Investigación con medicamentos de la Gerencia de Atención Integrada de Ciudad Real,

C E R T I F I C A

Que se ha evaluado la siguiente propuesta de estudio:

Título: **"Efectos del Entrenamiento Multicomponente frente al Entrenamiento Selectivo Cardiovascular como Tratamiento Coadyuvante en el control y tratamiento de la Hipertensión Arterial en sujetos Adultos desde la Atención Primaria".**
Código interno: C-557
Protocolo: Fecha 15/05/2021
HIP/CI: Fecha 13/12/2021

Este CEIm actuando como comité evaluador, emite dictamen **FAVORABLE** y acepta que dicho estudio sea realizado en los centros siguientes por los investigadores principales que se relacionan a continuación:

Investigador principal y Doctoranda: Isabel María López Ruiz.
Directores: Noelia González Gálvez, Fernando Lozano Ruiz-Poveda y José Abellán Huerta.

Y HACE CONSTAR QUE:

1º En la reunión celebrada el día 19 de julio de 2022 (Acta 07/2022) se decidió emitir el informe correspondiente al estudio de referencia.

2º En dicha reunión se cumplieron los requisitos establecidos en la legislación vigente y se cumplieron las normas de funcionamiento interno del Comité para que la decisión del citado CEIm sea válida.

3º El CEIm, tanto en su composición como en los PNT cumple las normas.

4º La composición actual del CEIm es la siguiente:

Presidente: Dª. Pilar Vicente Sánchez (Farmacia Hospitalaria GAICR).
Vicepresidente: D. César Lozano Suárez (Médico Atención Primaria GAICR).
Secretario: D. Francisco Javier Gómez Romero (Medicina Preventiva GAICR).
Vocales:

D. José Luis Albasanz Herrero	Facultad Ciencia Químicas Ciudad Real
D. Baltasar Baladrón Simal	Miembro lego.
Dª Ana M. García Pérez	FEA Medicina Interna GAICR
Dª Esther Pilar García Santos	FEA Cirugía Gral y Ap Digestivo GAICR
D. Alberto León Martín	Técnico de Salud. GAICR
D. Francisco J. López Cánovas	FEA Psiquiatría. GAICR
Dª María Dolores Moya Pérez	Aux. Administrativo CEIm. GAICR
D. José Ramón Muñoz Rodríguez	Investigador Unidad Investigación Traslacional
Dª María Isabel Porras Gallo	Facultad Medicina. Ciudad Real
D. Fco. Javier Redondo Calvo	FEA Anestesiología y Reanimación. GAICR
Dª Cristina Romero Blanco	Facultad Enfermería. Ciudad Real
Dª M. Mar Romero Fernández	Técnico Salud. GAI Puertollano
D. Carlos Salazar García	Farmacólogo Clínico GAICR
D. Antonio Tercero Calle	Asesoría Jurídica. GAICR

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13005 Ciudad Real (España)

Gerencia Atención Integrada

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En el caso de que algún miembro participe en el estudio o declare algún conflicto de interés no habrá participado en la evaluación, ni en el dictamen de la solicitud de autorización del mismo.

Compromiso contraídos por el investigador con respecto al Comité de Ética de la Investigación:

Se recuerda al investigador que la ejecución del estudio le supone los siguientes compromisos con el Comité:

- Se recuerda al investigador el requisito de solicitar a la AEMPS la publicación en el Registro Español de estudios clínicos al inicio de los estudios de seguimiento prospectivo y se recomienda para el resto de estudios observacionales con medicamentos (si procede).
- Ejecutar el estudio con arreglo a lo especificado en el protocolo, tanto en los aspectos científicos como en los aspectos éticos.
- Notificar al Comité todas las modificaciones o enmiendas en el estudio y solicitar una nueva evaluación de las relevantes.
- Enviar al Comité un informe final al término de la ejecución del estudio. Este informe deberá incluir los siguientes apartados:
  - Número de registro del estudio en bases de datos públicas de proyectos de investigación, si procede.
  - Memoria final del estudio, la enviada a las agencias reguladoras.
  - Publicación/es científica/s generada/s por el estudio.
  - Información (tipo y modo) transmitida a los sujetos del estudio sobre los resultados de la investigación y sobre los que afecten directamente a su salud (si procede)

Para que conste donde proceda y surta los efectos oportunos,

En Ciudad Real, a 19 de julio de 2022

COMITÉ DE ÉTICA DE INVESTIGACIÓN CON MEDICAMENTOS

Fdo.: Pilar Vicente Sánchez
Presidente CEIm

HOSPITAL GENERAL UNIVERSITARIO
CEIm
c/ Obispo Rafael Torija, s/n
13005 Ciudad Real (España)

ANEXO 3. Consentimiento Informado

ENSAYO CLINICO CORAZON Y SALUD

Fecha_____

HOJA DE INFORMACIÓN PARA EL PACIENTE

TÍTULO: Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria.

INVESTIGADORES: Invg. ppal. Dª. Isabel María López Ruiz, Dr. D. Fernando Lozano Ruiz-Poveda, Dra. Dª María Dolores Masiá Mondéjar y Dra. Dª. Noelia González Gálvez.

INTRODUCCIÓN

La enfermedad cardiovascular es la primera causa de muerte prematura en el mundo y la hipertensión arterial (HTA) el factor de riesgo cardiovascular más prevalente, siendo responsable de un incremento del riesgo de sufrir cardiopatías, encefalopatías y nefropatías, encabezando la lista de las enfermedades graves no transmisibles responsable de 10,4 millones de muertes al año.

Las intervenciones no farmacológicas (ITNF) deben ser claves para la prevención, control y tratamiento de la HTA y es aquí donde la práctica de ejercicio físico regular es determinante.

El objetivo del presente estudio es conocer los efectos de un programa de Entrenamiento Multicomponente (EMC) vs Entrenamiento Selectivo Cardiovascular (ESCV) sobre la presión arterial sistólica y diastólica; la presión arterial media; la presión de pulso; el doble producto; la frecuencia cardiaca basal; la composición corporal (peso, masa musculo esquelética, masa grasa y área de grasa visceral); la composición del agua corporal (agua intracelular, agua extracelular y ratio del agua extracelular); el ángulo de fase corporal; el índice de masa magra apendicular esquelética; el diámetro abdominal; la capacidad funcional; la fuerza muscular; la capacidad cardiorrespiratoria; y los valores de colesterol, HDL, LDL, triglicéridos y glucosaen sujetos adultos con HTA.

Para ello se realizará un ensayo clínico controlado aleatorizado con varios grupos de estudio simultáneos,grupo de EMC, grupo de ESCV continuo, grupo de ESCV fraccionado, yun grupo control sin intervención con ejercicio físico. La muestra será mixta, con un n=30 por grupo de adultos hipertensos controlados.

El periodo de intervención será de 3 meses(12 semanas), con una frecuencia de entrenamiento de 2 días/semana y con una duración por sesión de 60 minutos.

ENSAYO CLINICO CORAZON Y SALUD

Fecha_____

Se valorarán antes y después de las intervenciones las siguientes variables:

- ✓ Parámetros Hemodinámicos: la presión arterial sistólica y diastólica (PAS/PAD); presión arterial media (M.A.P); presión de pulso (P.P); doble producto (R.P.P) y frecuencia cardiaca basal (FCB).
- ✓ Análisis de composición corporal (ACC):
  - o Análisis músculo-grasa (peso [Kg]; masa músculo esquelética [Kg]; masa grasa corporal [Kg]).
  - o Análisis de obesidad (índice de masa corporal [Kg/m²]; porcentaje de grasa corporal [%]).
  - o Área de grasa visceral (cm²).
- ✓ Diámetro abdominal.
- ✓ Ángulo de fase
- ✓ Análisis de bioquímica: glucosa en sangre; creatinina; colesterol; HDL y LDL.
- ✓ Valoración capacidad cardiovascular (test clínico en cicloergómetro)
- ✓ Valoración de la fuerza muscular (test de velocidad de ejecución y test de fuerza de presión manual).
- ✓ Valoración Calidad de vida de la hipertensión Arterial (Cuestionario CHAL).

Su participación es voluntaria. Para ello lea esta hoja informativa y nosotros leaclararemos las dudas que le puedan surgir después de la explicación. Además,puede consultar con las personas que considere oportuno. Su negativa a participar osu retirada en cualquier momento no influirá negativamente en su tratamiento médico.No es necesario que justifique la decisión sobre su negativa o retirada.

HOJA DE INFORMACIÓN PARA EL PACIENTE

TÍTULO: Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria.

OBJETIVOS DEL ESTUDIO

El objetivo del presente estudio es conocer los efectos de un programa de Entrenamiento Multicomponente (EMC) vs Entrenamiento Selectivo Cardiovascular (ESCV) sobre la presión arterial sistólica y diastólica; la presión arterial media; la presión de pulso; el doble producto; la frecuencia cardiaca basal; la composición corporal (peso, masa musculo esquelética, masa grasa y área de grasa visceral); la composición del agua corporal (agua intracelular, agua extracelular y ratio del agua extracelular); el ángulo de fase corporal; el índice de masa magra apendicular esquelética; el diámetro abdominal; la capacidad funcional; la fuerza muscular; la capacidad cardiorrespiratoria; y los valores de colesterol, HDL, LDL, triglicéridos y glucosa en sujetos adultos con HTA.

PARTICIPACIÓN EN EL ESTUDIO

Se realizará un ensayo clínico controlado aleatorizado con varios grupos de intervención: grupo de EMC, grupo de ESCV continuo, grupo de ESCV fraccionado y un grupo control sin intervención con ejercicio físico. La muestra será mixta, con un n=30 por grupo de adultos hipertensos controlados.

El periodo de intervención será de 3 meses (12 semanas), con una frecuencia de entrenamiento de 2 días/semana y con una duración por sesión de 60 minutos.

Se valorarán antes y después de las intervenciones las siguientes variables:

- ✓ Parámetros Hemodinámicos: la presión arterial sistólica y diastólica (PAS/PAD); presión arterial media (M.A.P); presión de pulso (P.P); doble producto (R.P.P) y frecuencia cardiaca basal (FCB).

ENSAYO CLINICO CORAZON Y SALUD

- ✓ Análisis de composición corporal (ACC):
  - o Análisis músculo-grasa (peso [Kg]; masa músculo esquelética [Kg]; masa grasa corporal [Kg]).
  - o Análisis de obesidad (índice de masa corporal [Kg/m²]; porcentaje de grasa corporal [%]).
  - o Área de grasa visceral (cm²).
- ✓ Diámetro abdominal.
- ✓ Ángulo de fase
- ✓ Análisis de bioquímica: glucosa en sangre; creatinina; colesterol; HDL y LDL.
- ✓ Valoración capacidad cardiovascular (test clínico en cicloergómetro)
- ✓ Valoración de la fuerza muscular (test de velocidad de ejecución).
- ✓ Valoración Calidad de vida de la hipertensión Arterial (Cuestionario CHAL).

Su participación es voluntaria. Su negativa a participar o su retirada en cualquier momento no influirá negativamente en su tratamiento médico. No es necesario que justifique la decisión sobre su negativa o retirada.

POSIBLES BENEFICIOS

Si forma parte de alguno de los Grupos experimentales, Entrenamiento Multicomponente o Entrenamiento Selectivo Cardiovascular, podrá experimentar mejoras importantes para su salud que serán ratificadas gracias a las valoraciones pre y post intervención en las variables presión arterial sistólica y diastólica; la presión arterial media; la presión de pulso; el doble producto; la frecuencia cardiaca basal; la composición corporal (peso, masa musculo esquelética, masa grasa y área de grasa visceral); la composición del agua corporal (agua intracelular, agua extracelular y ratio del agua extracelular); el ángulo de fase corporal; el diámetro abdominal; la capacidad funcional; la fuerza muscular; la capacidad cardiorrespiratoria; y los valores de colesterol, HDL, LDL, triglicéridos y glucosa.

Además, si forma parte de alguno de los grupos experimentales disfrutará y se beneficiará sin coste alguno de 3 meses (12 semanas) de programa de entrenamiento supervisado 100% por profesionales del ejercicio físico, con diseños de entrenamientos seguros, funcionales y efectivos adaptados a cada persona.

ENSAYO CLINICO CORAZON Y SALUD

Fecha_____

HOJA DE INFORMACIÓN PARA EL PACIENTE

TÍTULO: Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria.

RIESGOS Y MOLESTIAS

No han sido descritos riesgos para la salud en los test descritos y que serán utilizados para la valoración inicial y final de la intervención; así como tampoco han sido descritos riesgos para salud de los practicantes en los programas de Entrenamiento Multicomponente o Selectivo Cardiovascular.

RETIRADA DEL ESTUDIO

Su participación en este estudio es completamente voluntaria y puede retirarse en cualquier momento.

PROTECCIÓN DE DATOS

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 INVESALUD, cuyo titular es la FUNDACIÓN UNIVERSITARIA SAN ANTONIO, con la finalidad de INVESTIGACIÓN Y DOCENCIA EN LAS ÁREAS DE CONOCIMIENTO CIENCIAS EXPERIMENTALES Y CIENCIAS DE LA SALUD. 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.

ENSAYO CLINICO CORAZON Y SALUD

Fecha_____

HOJA DE INFORMACIÓN PARA EL PACIENTE

TÍTULO: Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria.

COMPENSACIÓN ECONÓMICA

Usted no recibirá ninguna compensación económica por participar en el estudio.

INFORMACIÓN ADICIONAL

Durante la duración de este estudio puede formular cualquier pregunta que tenga, para ello póngase en contacto con:

Nombre: Isabel María López Ruiz

Teléfono: 926311625 o 617217275

ENSAYO CLINICO CORAZON Y SALUD

Fecha_____

CONSENTIMIENTO INFORMADO PARA EL PACIENTE

TÍTULO: Efectos del entrenamiento multicomponente frente al entrenamiento selectivo cardiovascular como tratamiento coadyuvante en el control y tratamiento de la hipertensión arterial en sujetos adultos desde la atención primaria.

Yo, ...con DNI .....

- He leído la hoja de información que se me ha entregado.
- He podido hacer preguntas sobre el estudio.
- He recibido suficiente información sobre el estudio.

He hablado con .....

Comprendo que mi participación es voluntaria.

Comprendo que puedo retirarme del estudio:

- Cuando quiera
- Sin tener que dar explicaciones
- Sin que ello repercuta en mis cuidados médicos

Por todo ello presto libremente mi conformidad para participar en el estudio y a que seme realicen las pruebas necesarias correspondientes a la participación en el estudio.

Firma de la paciente Firma del investigador

ANEXO 4. Cuestionario PAR-Q

Physical Activity Readiness Questionnaire - PAR-Q (revisado 2002)

PAR-Q & YOU

(Un Cuestionario para Personas de 15 a 69 años)

La actividad física regular es saludable y sana, y más personas cada día están comenzando a estar más activas. Ser más activo es seguro para la mayoría de las personas. Sin embargo, algunos individuos deben consultar a un médico antes de iniciar un programa de ejercicio o actividad física.

Si usted está planificando participar en programas de ejercicio o de actividad física, lo recomendado es que responda a las siete preguntas descritas más abajo. Si usted tiene entre 15 y 69 años de edad, el cuestionario PAR-Q le indicará si necesita consultar a su médico antes de iniciar un programa de ejercicio o actividad física. Si usted tiene más de 69 años de edad, y no está acostumbrado a estar activo, consulte a su médico.

El sentido común es la principal guía para contestar estas preguntas. Favor de leer las preguntas con cuidado y responder cada una honestamente; Marque SI o NO.

SÍ	NO	
☐	☐	1. ¿Alguna vez su médico le ha indicado que usted tiene un problema cardiovascular, y que solamente puede llevar a cabo ejercicios o actividad física si lo refiere un médico.
☐	☐	2. ¿Sufre de dolores frecuentes en el pecho cuando realiza algún tipo de actividad física?
☐	☐	3. ¿En el último mes, le ha dolido el pecho cuando no estaba haciendo actividad física?
☐	☐	4. ¿Con frecuencia pierde el equilibrio debido a mareos, o alguna vez ha perdido el conocimiento?
☐	☐	5. ¿Tiene problemas en los huesos o articulaciones (por ejemplo, en la espalda, rodillas o cadera) que pudiera agravarse al aumentar la actividad física?
☐	☐	6. ¿Al presente, le receta su medico medicamentos (por ejemplo, pastillas de agua) para la presión arterial o problemas con el corazón?
☐	☐	7. ¿Existe alguna otra razón por la cual no debería participar en un programa de actividad física?

Si usted contestó

SÍ a una o más preguntas:

Hable con su médico por teléfono o en persona ANTES de empezar a estar más activo físicamente, o ANTES de tener una evaluación de su aptitud física. Dígale a su médico que realizó este cuestionario y las preguntas que usted respondió que SI.

- Usted puede estar listo para realizar cualquier actividad que desee, siempre y cuando comience lenta y gradualmente. O bien, puede que tenga que restringir su actividad a las que sea mas segura para usted. Hable con su médico sobre el tipo de actividades que desea participar y siga su consejo.
- Busque programas en lugares especializados que sean seguros y beneficiosos para usted.

No todas preguntas:

Si usted contestó NO honestamente a todas las preguntas, entonces puede estar razonablemente seguro que puede:

- Comenzar a ser más activo físicamente, pero con un enfoque lento y que se progrese gradualmente. Esta es la manera más segura y fácil.
- Formar parte de una evaluación de la aptitud física; esta es una manera excelente para determinar su aptitud física de base, lo cual le ayuda a planificar la mejor estrategia de vivir activamente. También, es muy recomendable que usted se evalúe la presión arteria. Si su lectura se encuentra sobre 144/94, entonces, hable con su médico antes de ser más activo físicamente.

DEMORE EL INICIO DE SER MÁS ACTIVO:

- Si usted no se siente bien a causa de una enfermedad temporera, tal como un resfriado o fiebre, entonces lo sugerido es esperar hasta que se recupere por completo; o
- Si usted está o puede estar embarazada, hable con su médico antes de comenzar a estar físicamente más activa.

POR FAVOR: Si un cambio en su salud lo obliga a responder SI a cualquiera de las preguntas, es importante que esta situación se le informe a su médico o entrenador personal. Pregunte si debe modificar su plan de ejercicio o actividad física.

Uso Informado de PAR-Q: La Sociedad Canadiense de Fisiología del Ejercicio, y sus agentes, no asumen ninguna responsabilidad legal para las personas que realizan ejercicio o actividad física; en caso de duda después, de completar este cuestionario, consulte primero a su médico.

No se permiten cambios. Se puede fotocopiar el PAR-Q, únicamente si se emplea todo el formulario.

NOTA: Si se requiere administrar el PAR-Q antes que el participante se incorpore a un programa de ejercicio/actividad física, o se someta a pruebas de aptitud física, esta sección se puede utilizar para propósitos administrativos o legales:

"Yo he leído, entendido y completado el cuestionario. Todas las preguntas fueron respondidas a mi entera satisfacción."

Nombre: _____

Firma: _____ Fecha: _____

FIRMA DEL PARIENTE: _____ TESTIGO: _____
o TUTOR (para participantes menores edad)

NOTA: Este cuestionario es valido hasta un máximo de 12 meses, a partir de la fecha en que se completa. El mismo se invalida si su estado de salud requiere contestar SI en alguna de las siete preguntas.

NOTA. Obtenido de: The Physical Activity Readiness Questionnaire: PAR-Q & YOU, por Canadian Society for Exercise Physiology, 2002. Copyright 2002 por Canadian Society for Exercise Physiology, www.csep.ca/forms. Recuperado de http://www.csep.ca/cmfiles/publications/parq/par-q.pdf

ANEXO 5. Cuestionario Sociodemográfico

CUESTIONARIO SOCIODEMOGRÁFICO

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
- ☐ Femenino

- ☐ Soltero/a
- ☐ Casado/a o Pareja de hecho
- ☐ Separado/a o divorciado/a
- ☐ Viudo/a

4. Nacionalidad: _____

Municipio de residencia:_____

5. Actividad física

¿Práctica algún tipo de actividad física (caminar, aeróbic, gimnasia, centro deportivo, Pilates, correr, etc.)?

_____

¿Cuál?_____

¿Con qué frecuencia?_____

7. Nivel de estudios

- ☐ Sin estudios
- ☐ Básicos (Graduado escolar)
- ☐ Secundarios (ESO, bachillerato)
- ☐ Superiores (ciclos formativos/grado medio o superior)
- ☐ Estudios universitarios

6. Ocupación laboral

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

8. Viviendo o no en compañía

- ☐ Con su esposo/a
- ☐ Con un compañero/a
- ☐ 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**

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						

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)						
30. Problemas con la menstruación (sólo mujeres)						
31. Lesiones o problemas permanentes causados por un accidente						
32. Síndrome de apnea del sueño						
Otras (Indicar)						

ANEXO 6. Cuestionario de Salud SF36

CUESTIONARIO SF-36 SOBRE EL ESTADO DE SALUD

Las preguntas que siguen se refieren a lo que usted piensa sobre su salud. Sus respuestas permitirán saber cómo se encuentra usted y hasta qué punto es capaz de hacer sus actividades habituales.

Conteste cada pregunta tal como se indica. Si no está seguro/a de cómo responder a una pregunta, por favor conteste lo que le parezca más cierto.

1. En general, usted diría que su salud es: (marque un solo número)

Excelente ……..1
Muy buena ……. 2
Buena ……. 3
Regular ……. 4
Mala ……. 5

2. ¿Cómo diría usted que es su salud actual, comparada con la de hace un año? (marque un solo número)

Mucho mejor ahora que hace un año ……. 1
Algo mejor ahora que hace un año ……. 2
Más o menos igual que hace un año ……. 3
Algo peor ahora que hace un año ……. 4
Mucho peor ahora que hace un año ……. 5

3. Las siguientes preguntas se refieren a actividades o cosas que usted podría hacer en un día normal. Su salud actual, ¿le limita para hacer esas actividades o cosas? Si es así, ¿cuánto?

ACTIVIDADES	**Sí, melimita mucho**	**Sí, melimita unpoco**	**No, no me limita nada**
a. Esfuerzos intensos, tales como correr, levantar objetos pesados, o participar en deportes agotadores	1	2	3
b. **Esfuerzos moderados**, como mover una mesa, pasar la aspiradora, jugar a los bolos o caminar más de una hora	1	2	3
c. Coger o llevar la bolsa de la compra	1	2	3

d. Subir **varios** pisos por la escalera	1	2	3
e. Subir **un solo** piso por la escalera	1	2	3
f. Agacharse, arrodillarse o ponerse en cuclillas	1	2	3
g. Caminar **un kilómetro o más**	1	2	3
h. Caminar **varias manzanas** (varios centenares de metros)	1	2	3
i. Caminar **una sola manzana** (unos100 metros)	1	2	3
j. Bañarse o vestirse por sí mismo	1	2	3

4. Durante las 4 últimas semanas, ¿ha tenido alguno de los siguientes problemas en su trabajo o en sus actividades cotidianas, a causa su salud física?

	SÍ	**NO**
a. ¿Tuvo que **reducir el tiempo** dedicado al trabajo o a sus actividades cotidianas?	1	2
b. ¿**Hizo menos** de lo que hubiera querido hacer?	1	2
c. ¿Tuvo que **dejar de hacer algunas tareas** en su trabajo en sus actividades cotidianas?	1	2
d. ¿Tuvo **dificultad** para hacer su trabajo o sus actividades cotidianas (por ejemplo, le costó más de lo normal)?	1	2

5. Durante las 4 últimas semanas, ¿ha tenido alguno de los siguientes problemas en su trabajo o en sus actividades cotidianas, a causa de algún problema emocional (como estar triste, deprimido, o nervioso)?

	SÍ	**NO**
a. ¿Tuvo que **reducir el tiempo** dedicado al trabajo o a sus actividades cotidianas, **por algún problema emocional**?	1	2

b. ¿**Hizo menos** de lo que hubiera querido hacer, **por algún problema emocional**?	1	2
c. ¿No hizo su trabajo sus actividades cotidianas tan **cuidadosamente** como de costumbre, **por algún problema emocional**?	1	2

6. Durante las 4 últimas semanas, ¿hasta qué puntos u salud física o los problemas emocionales han dificultado sus actividades sociales habituales con la familia, los amigos, los vecinos u otras personas? (marque un solo número)

Nada 1
Un poco 2
Regular..... 3
Bastante 4
Mucho 5

7. ¿Tuvo dolor en alguna parte del cuerpo durante las 4 últimas semanas? (marque un solo número)

No, ninguno 1
Sí, muy poco 2
Sí, un poco 3
Sí, moderado 4
Sí, mucho 5
Sí, muchísimo 6

8. Durante las 4 últimas semanas, ¿hasta qué punto el dolor le ha dificultado su trabajo habitual (incluido el trabajo fuera de casa y las tareas domésticas)? (marque un solo número)

Nada 1
Un poco 2
Regular 3
Bastante 4
Mucho 5

9. Las preguntas que siguen se refieren a cómo se ha sentido y cómo le han ido las cosas durante las 4 últimas semanas. En cada pregunta responda lo que se parezca más a cómo se ha sentido usted. Durante las últimas 4 semanas ¿cuánto tiempo...

	Siempre	Casi siempre	Muchas veces	Algunas veces	Sólo alguna vez	Nunca
a. Se sintió lleno de vitalidad?	1	2	3	4	5	6
b. Estuvo muy nervioso?	1	2	3	4	5	6
c. Se sintió tan bajo de moral que nada podía animarle?	1	2	3	4	5	6
d. Se sintió calmado y tranquilo?	1	2	3	4	5	6
e. Tuvo mucha energía?	1	2	3	4	5	6
f. Se sintió desanimado y triste?	1	2	3	4	5	6
g. Se sintió agotado?	1	2	3	4	5	6
h. Se sintió feliz?	1	2	3	4	5	6
i. Se sintió cansado?	1	2	3	4	5	6

10. Durante las 4 últimas semanas, ¿con qué frecuencia la salud física o los problemas emocionales le han dificultad o sus actividades sociales (como visitar a los amigos o familiares)?

(marqueunsolonúmero)
Siempre 1
Casi siempre 2
Algunas veces 3
Sólo alguna vez 4
Nunca 5

ANEXO 7. Escala de Satisfacción con la Vida

ESCALA DE SATISFACCIÓN CON LA VIDA

Por favor, indica tu grado de acuerdo con cada frase rodeando con un círculo el número apropiado (solo uno por afirmación). Por favor, sé sincero con tu respuesta.

	Muy en desacuerdo		Neutro		Muy de acuerdo
En la mayoría de los aspectos de mi vida es como yo quiero que sea	1	2	3	4	5
Las circunstancias de mi vida son muy buenas	1	2	3	4	5
Estoy satisfecho con mi vida	1	2	3	4	5
Hasta ahora he conseguido de la vida las cosas que considero importantes	1	2	3	4	5
Si pudiera vivir mi vida otra vez no cambiaría casi nada	1	2	3	4	5

ANEXO 8. Hoja de Registro Valoración Hemodinámica

ENSAYO CLÍNICO CORAZÓN Y SALUD

UCAM UNIVERSIDAD Oxigeno Sport & Wellness

Hoja de Registro Parámetros Hemodinámicos

Participante	Registro	Fecha	PA Sistólica	PA Diastólica	PA Media	Presión de Pulso	Doble Producto	FC Basal
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

Participante	Registro	Fecha	PA Sistólica	PA Diastólica	PA Media	Presión de Pulso	Doble Producto	FC Basal
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

Participante	Registro	Fecha	PA Sistólica	PA Diastólica	PA Media	Presión de Pulso	Doble Producto	FC Basal
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

ANEXO 9. Hoja de Registro Valoración Composición Corporal

ENSAYO CLÍNICO CORAZÓN Y SALUD

Hoja de Registro Composición Corporal

Participante	Registro	Fecha	Peso (Kg)	M Magra (Kg)	M Grasa (Kg)	AGV (cm)	IMC (Kg/m²)	P Abd (cm)	Ángulo de Fase
Nombre:	Pre-Inter	--/--/----							
Apellidos:	Pos-Inter	--/--/----							

Participante	Registro	Fecha	Peso (Kg)	M Magra (Kg)	M Grasa (Kg)	AGV (cm)	IMC (Kg/m²)	P Abd (cm)	Ángulo de Fase
Nombre:	Pre-Inter	--/--/----							
Apellidos:	Pos-Inter	--/--/----							

Participante	Registro	Fecha	Peso (Kg)	M Magra (Kg)	M Grasa (Kg)	AGV (cm)	IMC (Kg/m²)	P Abd (cm)	Ángulo de Fase
Nombre:	Pre-Inter	--/--/----							
Apellidos:	Pos-Inter	--/--/----							

ANEXO 10. Hoja de Registro Valoración Bioquímica de Sangre

ENSAYO CLÍNICO CORAZÓN Y SALUD

Hoja de Registro Perfil Lipídico y Glucosa

Participante	Registro	Fecha	CT (mg/dl)	TGL (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	Glucosa (mg/dl)	Creatinina
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

Participante	Registro	Fecha	CT (mg/dl)	TGL (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	Glucosa (mg/dl)	Creatinina
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

Participante	Registro	Fecha	CT (mg/dl)	TGL (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	Glucosa (mg/dl)	Creatinina
Nombre:	Pre-Inter	--/--/----						
Apellidos:	Pos-Inter	--/--/----						

ANEXO 11. Hoja de Registro Valoración HandGrip

ENSAYO CLÍNICO CORAZÓN Y SALUD

Hoja de Registro Fuerza de Agarre Manual (HandGrip)

Participante	Registro	Fecha	Mano D (Kg)	Mano I (Kg)
Nombre:	Pre-Inter	--/--/----		
Apellidos:	Pos-Inter	--/--/----		

Participante	Registro	Fecha	Peso (Kg)	M Magra (Kg)
Nombre:	Pre-Inter	--/--/----		
Apellidos:	Pos-Inter	--/--/----		

Participante	Registro	Fecha	Peso (Kg)	M Magra (Kg)
Nombre:	Pre-Inter	--/--/----		
Apellidos:	Pos-Inter	--/--/----		

ANEXO 12. Hoja de Registro Valoración Fuerza Máxima

ENSAYO CLÍNICO CORAZÓN Y SALUD

Hoja de Registro Fuerza Máxima

Valoración a través de la Velocidad de Ejecución

Registro Miembros Superiores Ejercicio Press Banca						
Participante	Registro	Fecha	1RM (Kg)	50%-1RM (Kg)	VMP al 50% (m/s)	Nº Rept
Nombre:	Pre-Inter	--/--/----				
Apellidos:	Pos-Inter	--/--/----				
Registro Miembros Inferiores Ejercicio Sentadilla						
Participante	Registro	Fecha	1RM (Kg)	60%-1RM (Kg)	VMP al 60% (m/s)	Nº Rept
Nombre:	Pre-Inter	--/--/----				
Apellidos:	Pos-Inter	--/--/----				

ANEXO 13. Hoja de Registro Valoración Capacidad Cardiorrespiratoria

ENSAYO CLÍNICO CORAZÓN Y SALUD

Hoja de Registro Capacidad Cardiorrespiratoria

Valoración Test Clínico en Cicloergómetro

Participante	Registro	Fecha	WATT	VO_2Pico (ml-kg-min)	FC Máxima	FC Media	RPE Borg
Nombre:	Pre-Inter	--/--/----					
Apellidos:	Pos-Inter	--/--/----					

Participante	Registro	Fecha	WATT	VO_2Pico (ml-kg-min)	FC Máxima	FC Media	RPE Borg
Nombre:	Pre-Inter	--/--/----					
Apellidos:	Pos-Inter	--/--/----					

Participante	Registro	Fecha	WATT	VO_2Pico (ml-kg-min)	FC Máxima	FC Media	RPE Borg
Nombre:	Pre-Inter	--/--/----					
Apellidos:	Pos-Inter	--/--/----					

ANEXO 14. Estudio 1. Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

sports

MDPI

Review

Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Abstract: (1) Background: Non-pharmacological interventions have demonstrated efficacy in the prevention, management, and control of hypertension. Multicomponent training confers a host of benefits to the general populace. The aim of this research was to assess the impact of multicomponent training on the blood pressure of adults with hypertension and ascertain the nature of the dose–response relationship. (2) Methods: This systematic review adhered to the PRISMA guidelines and was registered in PROSPERO. Eight studies were included, following a literature search across PubMed, Web of Science, Cochrane, and EBSCO. Randomized controlled trials implementing multicomponent training interventions on adults with hypertension were considered for inclusion. A quality assessment was performed using the PEDro scale, with a random-effects model utilized for all analyses. (3) Results: Multicomponent training yielded a significant reduction in systolic (MD = −10.40, $p < 0.001$) and diastolic (MD = −5.97, $p < 0.001$) blood pressure relative to the control group. Interventions lasting over 14 weeks with a minimum frequency of three sessions per week, each lasting 60 min, were deemed most effective. (4) Conclusion: An optimal training intensity was achieved with 30 min of aerobic exercise at 75% of the heart rate reserve, whereas sets of 10 repetitions at 75% of one repetition maximum produced the best outcomes in strength training.

Keywords: blood pressure; exercise; physical activity; cardiovascular disease

check for updates

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1. Introduction

Cardiovascular disease is the leading cause of premature death worldwide, and hypertension is one of its most prevalent risk factors [1,2]. Approximately one-third of the world's adult population suffers from hypertension, a factor that increases the risks of heart disease, encephalopathy, and kidney disease, with hypertension topping the list of serious, non-communicable diseases responsible for 10.4 million deaths per year [3].

Non-pharmacological interventions have been shown to be effective in the prevention, management, and control of hypertension [4]. The World Health Organization recommend that all adults should undertake at least 150 min of moderate-intensity activity or at least 75 min of vigorous-intensity physical activity, or some equivalent combination of moderate-intensity and vigorous-intensity aerobic physical activity, per week. In addition, the guidelines recommend regular muscle-strengthening activity for all age groups [5]. In this regard, the effect of cardiovascular training on blood pressure levels has been well established in the literature, with reductions ranging from −4.9 to −12 mm Hg for systolic blood pressure (SBP) and from −3.4 to −5.8 mm Hg for diastolic blood pressure (DBP) [6]. Strength training has shown improvements in blood pressure ranging from −3.0 to −4.7 mm Hg for SBP and from −3.2 to −3.8 mm Hg for DBP [6].

A description of the combined effect of both cardiovascular and strength training has been attempted. Multicomponent training has been shown to be more effective than aerobic training for improving some variables [7] and has been widely used and recommended in the older adult population to reduce frailty [8]. In multicomponent training, work is performed with many types of exercise by combining the physical capacities of strength, cardiovascular endurance, flexibility, and balance in the same session [9]. This training has shown positive effects on the health of the adults, with haemodynamic improvements and improvements in arterial stiffness observed [10], as recommended by the American College of Sports Medicine and by the American Heart Association [11].

Three similar systematic reviews have been conducted thus far. However, some aspects should be taken into consideration. The study by Corso et al. [12] included subjects with and without cardiovascular pathologies, such as diabetes, as well as subjects with hypertension; it also included training in a single session (multicomponent training) and in several sessions (concurrent training). The statistical analysis with meta-analyses by Herrod et al. [13] focused on the older adult population, and Pescatello et al. [14] did not include meta-analyses.

On the other hand, many differences have been observed between the dosage of the training protocols applied (time, frequency, duration, intensity, or order of components) [15–23], and a good understanding of the optimal dosage of the multicomponent training according to the blood pressure levels of patients with hypertension would help optimise the prescription, control, and management of hypertension.

The present systematic review and meta-analysis hypothesises that (a) multicomponent training will be effective in reducing systolic and diastolic hypertension levels in subjects with hypertension, and (b) the multicomponent training protocol that will show the greatest benefits for blood pressure will apply moderate to vigorous intensities in cardiovascular work and moderate to high intensities in strength training. In addition, the present systematic review with a meta-analysis aims (a) to evaluate the effects of multicomponent training on SBP and DBP levels of adults with hypertension, and (b) to identify the optimal dosage of multicomponent training to manage hypertension in adults.

2. Materials and Methods

2.1. Study Design

This systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [24]. In addition, this research followed the Cochrane Handbook for Systematic Reviews of Interventions [25] and was registered in PROSPERO (number CRD42021247395).

2.2. Eligibility Criteria

The inclusion criteria for the articles were (a) a randomised controlled trial (RCT) design, (b) the study of adults (30–80 years old) with hypertension, (c) a multicomponent training intervention, (d) the inclusion of a control group that did not engage in any form of exercise, (e) 100% supervision, and (f) articles written in English, Spanish, or Portuguese.

The exclusion criteria were (a) multicomponent training that did not include physical exercise, (b) a sample composed of pregnant women and/or patients with hypertensive and with severe diseases that precluded safe physical exercise (unstable coronary artery disease, heart or kidney failure, severe pulmonary hypertension, or uncontrolled diabetes), and (c) short communications, notes, letters, review articles, or brief reports.

2.3. Search Strategy

Four electronic databases (PubMed, Cochrane, WOS, and EBSCO) were used for the search, which ended in April 2022. No limitations for the starting year were defined in the search. The following search terms were used: hypertension, blood pressure, systolic, diastolic, and hypertensive, which were combined using the Boolean AND operator, with the following: exercise, training, sports, physical*, rehabilitat*, fit*, train*, strength*, aerobic*,

endurance*, weight*, HIIT, MICT, fitness, resistance, combined, and multicomponent. The search strategy used in each database is detailed in Supplementary Table S1. A total of nine studies were included in the study (Figure 1).

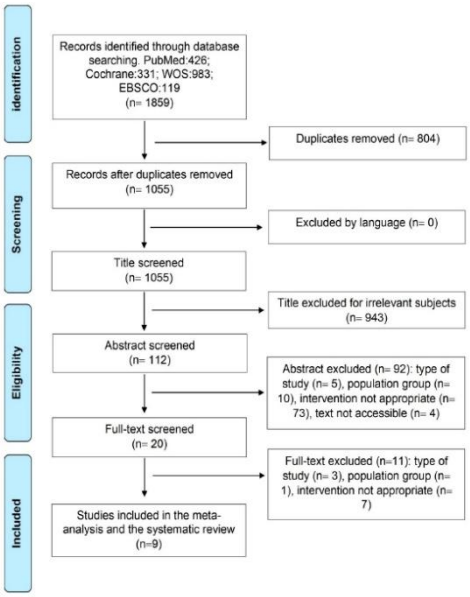


Figure 1. Flow chart of studies searched, selected and included.

2.4. Data Collection and Synthesis

Two reviewers (I.L.R. and N.G.G.) independently screened the literature in the selected databases using the search terms, considering the inclusion and exclusion criteria. In the case of any discrepancy regarding the inclusion of a given study, the data extraction or assessment were repeated without looking at the reviewer's previous information.

2.5. Data Extraction and Study Quality

A Physiotherapy Evidence Database (PEDro) score was used to assess the individual study of the quality. The score obtained showed a strong validity and inter-rater reliability for the assessment of RCTs [26–28]. A risk of bias summary graph was created to identify the authors' judgments, broken down according to each risk of bias criterion in all included studies.

Data extraction (Table 1) and a quality assessment were performed by two reviewers (I.L.R. and N.G.G.) independently. Disagreements were resolved by repeating the data extraction or assessment without looking at the information previously reported by the reviewer. To determine the inter-reviewer reliability, Cohen's Kappa was calculated [29] (Kappa = 0.899). To assess the risk of bias, Egger's publication bias test [26] and Rosenthal's failsafe-N [27] were calculated, and funnel plots were created. The ability of Egger's test to detect bias when a meta-analysis is based on a small number of studies is limited [30]. In addition, the inclusion of at least 10 studies in the meta-analysis are necessary to perform it [26].

Table 1. Data extraction for each included study.

Studies	Sample	Age	Treatment	Inclusion Criteria	Main Variables
Oliveira et al. [23]	EG = 13 CG = 10	62.65 ± 6.0 years	Diuretics; ARBs II; ACE inhibitors	Age ≥ 50 years; controlled HTN; medical clearance for exercise; no physical activity in the last 6 months; no serious medical conditions	BP; isometric maximal strength; body composition; VO^2
Schoeder et al. [22]	EG (MCT) = 18; (AT), (ST) and (CG) = 17	45–74 years 58 ± 7	Untreated	SBP 120–149 and DBP 80–99 mm Hg without medication; BMI 25–40 kg/m^2; sedentary; no serious medical conditions; non-smoker; non-pregnant	BP; HR; BMI; body composition; cardiorespiratory fitness; strength
Masroor et al. [21]	EG = 15 CG = 13	30–50 years 40.45 ± 4.2	A drug (not specified)	Sedentary women; premenopausal; stage 1 or 2 HTN; no serious medical conditions; no physical activity in the last 6 months	BP; HRV
Lima et al. [20]	EG (MCT) and (AT)= 15; CG = 14	60–75 years	Hydrochlorothiazide; ACE inhibitors; ARBs II	Antihypertensive medication; SBP < 160 mm Hg and DBP 105 mm Hg; non-smokers; no serious medical conditions; not obese II or III	BP; blood markers; cardiac hypertrophy; body composition; VO^2max
Son et al. [19]	EG = 10; CG = 10	72–85 years 75 ± 2	Untreated	Postmenopausal women; stage 1 HTN; non-obese; non-smokers; sedentary; non-medicated	BP; body composition; functional capacity; VO^2max; arterial stiffness; endothelin-1; nitrate
Guimaraes et al. [18]	EG = 16; CG = 16	40–65 years 53.7 ± 6.0	Diuretics; CCBs; ACE inhibitors; ARBs II; Beta-blockers	HBP >5 years; use of three antihypertensive drugs; no serious medical conditions; no physical activity in the last 6 months; non-smokers	BP; VO^2max
Dos Santos et al. [17]	EG (TST) = 20; (EST) and CG = 20	60–65 years 63.1 ± 2.3	CCBs; ACE inhibitors; ARBs II	Female; HTN; SBP < 180 and DBP < 110 mm Hg; sedentary; not diabetic; not on drugs and/or alcohol	BP; biochemical parameters
Sousa et al. [16]	EG (MCT) = 16 (AT) = 15, CG = 17	65–75 years (69.1 ± 5.0)	A drug (not specified)	Older men; no diabetes; no severe obesity; no severe hypertension; no neurological; mental or cognitive impairment; no physical impairment	BP; strength; lower limb aerobic endurance; body fatness
Stewart et al. [15]	EG = 51; CG = 53	55–75 years 63.6 ± 5.7	Untreated	Untreated mild hypertension; no physical activity in the last 6 months; non-smokers; no diabetes; no serious diseases	BP; VO^2 max; strength; body composition; arterial stiffness

AT: aerobic training; ST: strength training; EST: eccentric strength training; TST: traditional strength training; MCT: multicomponent training; HR: heart rate; CG: control group; EG: experimental group.; HTN: arterial hypertension; BMI: body mass index; BP: blood pressure; DBP: diastolic blood pressure; SBP: systolic blood pressure; HRV: heart rate variability.

2.6. Statistical Analysis

R software, version 3.6.0., Copyright (C) 2019 (R Foundation for Statistical Computing, Vienna, Austria), was used with the metacont package to perform the meta-analysis. The forest plots were created using the forestplot package. For continuous data, the changes in the mean (M) and standard deviation (SD) between the baseline and final (pre–post-intervention) measurements of SBP and DBP values were used. Some studies had more than one experimental group and were treated as other subgroups in the analysis. We used the DerSimonian–Laird (Cohen's) clustering method and assessed heterogeneity using Cochrane's Q test (Chi^2), Higgins' I^2, and significance (p) to determine the appropriateness of applying a fixed or random effects model for the pooled analysis. If there was evidence of between-study heterogeneity ($I^2 > 50\%$, $p > 0.05$), random-effect estimates were described [31].

To infer the pooled estimated standardised mean difference (MD), a meta-analysis with a random effects model was carried out [32]. The DerSimonian–Laird (Cohen's) MD

was interpreted by Cohen as small (0 to 0.2), medium (0.3 to 0.7), or large (≥0.8) [33]. Significant differences were determined at $p < 0.05$.

3. Results

3.1. Search Results and Study Characteristics

The mean age of the sample was 60.7 ± 10.4 years, the mean duration of the intervention was 12 ± 8.3 weeks (range 4–32), and all interventions were supervised (Table 2).

3.2. Risk of Bias

Table 3 shows the score obtained on the PEDro scale for each of the articles included. The results show that quality obtained between eight and 10 points and was thus considered to be "high quality". Figure 2 shows the risk of bias summary: the authors' judgements are broken down according to each risk of bias criterion across all included studies.

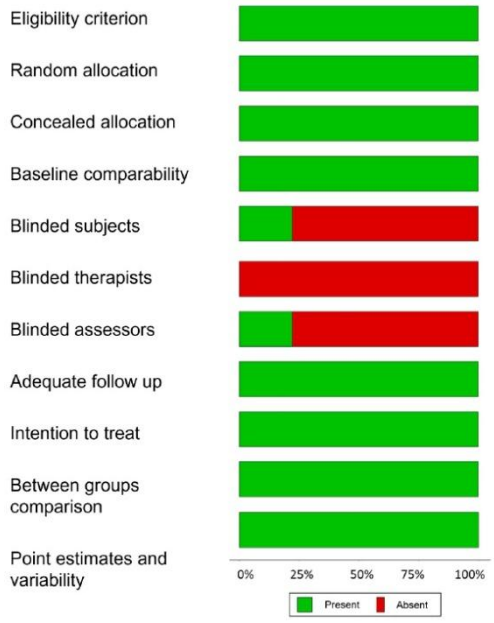


Figure 2. Risk of bias summary: authors' judgements broken down according to each risk of bias criterion across all included studies.

Table 2. Intervention programmes of the studies analysed.

Studies	Start	Training	Finish	T, F, D
Oliveira et al. [23]	10′ running and S	Aerobic: 25′ on treadmill, progressing the intensity by 5% every two weeks from 70% HRR to 80% HRR. Strength: 6 exercises (rowing, standing bench press, arm curl, knee extension, knee flexion, forward march with a resistance band) × 2 sets × 15 repetitions × 30″ between sets and exercises. Intensity measured with OMNI-Resistance exercise scale (RES), progressing from 5 RPE progressing to 7 RPE and with the elastic bands from low extensions to high tensions.	10′ S and ME	8 wks, 3 days/wk, 70′
Schoeder et al. [22]	-	Aerobic: 30′ on treadmill or cycle ergometer at 40% HRR, progressing to 70% HRR. Strength: 30′ with 8 exercises (chest press, shoulder press, pull-down, lumbar extension, abdominal crunches, torso rotation, biceps curl, triceps extension, leg press, quadriceps extension, leg flexion and hip abduction) × 2 sets of 18–20 reps max until progressing to 3 sets of 10–14 reps max, with 1–2′ rest between sets.	-	8 wks, 3 days/wk, 60′
Masroor et al. [21]	5′ treadmill at 40% of HRmax	Aerobic: 20′ treadmill at 50–80% HRmax (intensity increased gradually over 4 weeks) Strength: 5 exercises (bicep curls, triceps extensions, abdominal crunches, leg curls, and knee extensions) × 3 sets × 10 reps at an intensity of 50–80% of 1 RM (intensity was gradually increased over 4 weeks).	5′ treadmill at 40% of HRmax	4 wks, 5 days/wk, 50′–60′
Lima et al. [20]	5′	Strength: 9 strength exercises (leg press, 45° leg press or bench press, bench extensor, front bench with handle, seated bench press, upright rowing, plantar flexion, seated rowing and crunches) × 15 repetitions (upper limbs) and 20 repetitions (lower limbs and trunk) with an intensity of 50–60% 1 RM. From week 1 to 4, they performed 1 round, and from week 5 to 10, 2 rounds. Aerobic: 20′ on treadmill from week 1 to 4 and 30′ from week 5 to 10. The intensity of the exercise was based on the physical condition of each participant.	-	10 wks, 3 days/wk, 40′–60′
Son et al. [19]	5′ SS	Strength: 20′ exercises with elastic bands; 10 exercises (seated row, bicep curl, shoulder flexion, elbow flexion, push-up; hip flexion, hip extension, calf raise, leg press, and squats). Aerobic: 30′ of walking at an exercise intensity of 40% to 50% HRR from weeks 1 to 4 and 60% to 70% HRR from weeks 9–12.	5′ SS	12 wks, 3 days/wk 60′
Guimaraes et al. [18]	5′	Strength: 20′ calisthenics in water (upper and lower limbs). Aerobic: 30′ walking in water between 11 and 13 on the Borg scale.	5′ S	12 wks, 3 days/wk, 60′

Table 2. *Cont.*

Studies	Start	Training	Finish	T, F, D
Dos Santos et al. [17]	TST	Strength: 7 exercises (bench press with barbell, leg press, trunk extension, leg extension, arm curl, dorsiflexion, and lateral raises). Week 1 to 5 at 70% 10 RM, week 6 to 11 at 80% of 10 RM, and week 12 to 16 at 90% of 10 RM. 3 sets × 10 reps. Aerobic: 20′ on a treadmill at 65–75% HRR.	-	16 wks, 3 days/wk, 50′–60′
	EST	Strength: work 30% 1 RM more than in EFT. Same resistance work.	-	
Sousa et al. [16]	10′ walking and S	Two days of training on land and one day in the water. Aerobic: 30′ with a choice between walking, jogging, or dancing with moderate intensity; in addition, 10′ of muscle resistance with 3 exercises (with own body weight, and upper and lower body), 3 sets, 15–20 repetitions. The aquatic session: relay races, water volleyball, and water polo. Strength: 6 exercises (bench press, leg press, lateral leg extension, leg extension, leg curl, military press, leg curl, and arm curl) at 65%R 1 RM × 3 sets × 10–12 reps (MC1); 75%RM. 24 × 3 sets × 8–10 reps (MC2); 70%RM × 3 sets × 8–10 reps (MC3); 65%RM × 3 sets × 10–12 reps (MC4).	5′ S	32 wks, 3 days/wk, 60′
Stewart et al. [15]	S	Strength: 7 exercises (latissimus dorsi pull down, leg extension, leg curl, bench press, leg press, shoulder press, and seated mid-row) × 2 sets × 10–15 reps at 50% 1 RM. Aerobic: 45′ with a choice of treadmill, exercise bike, or stair climber. Intensity between 60 and 90% HRmax.	-	24 wks, 3 days/wk, >60′

′: minutes; 1 RM: 1 repetition maximum; D: duration/session; S: stretching; SS: static stretching; EST: eccentric strength training; TST: traditional strength training; F: weekly frequency; HRmax: maximum heart rate; HRR: heart rate reserve; MC: microcycle; ME: mobility exercise; Reps: repetitions; WKS: weeks; T: intervention time; RPE: rate of perceived exertion.

Table 3. Assessment of the methodological quality (PEDro scale) of the articles included.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Total
Oliveira et al. [23]	1	1	1	1	1	0	0	1	1	1	1	9
Schroeder et al. [22]	1	1	1	1	0	0	1	1	1	1	1	9
Masroor et al. [21]	1	1	1	1	1	0	1	1	1	1	1	10
Lima et al. [20]	1	1	1	1	0	0	0	1	1	1	1	8
Son et al. [19]	1	1	1	1	0	0	0	1	1	1	1	8
Guimaraes et al. [18]	1	1	1	1	0	0	0	1	1	1	1	8
Dos Santos et al. [17]	1	1	1	1	0	0	0	1	1	1	1	8
Sousa et al. [16]	1	1	1	1	0	0	0	1	1	1	1	8
Stewart et al. [15]	1	1	1	1	0	0	0	1	1	1	1	8

C1: choice criteria were specified; C2: subjects were randomly assigned to groups; C3: assignment was concealed; C4: groups were similar at baseline in relation to the most important prognostic indicators; C5: all subjects were blinded; C6: all therapists administering therapy were blinded; C7: all assessors measuring at least one key outcome were blinded; C8: measures of at least one of the key outcomes were obtained from more than 85% of the subjects initially assigned to the groups; C9: results were presented for all subjects who received treatment or were assigned to the control group or, when this could not be carried out, data for at least one key outcome were analysed on an intention-to-treat basis; C10: results of statistical comparisons between groups were reported for at least one key outcome; C11: the study provides point-in-time and variability measures for at least one key outcome.

3.3. Effect of the Interventions

All the included studies showed significant improvements in SBP and DBP levels [15–21,23] except for the study by Schroeder et al. [22], which showed no improvements in peripheral and central systolic blood pressure levels; however, it did show improvements in peripheral and central diastolic blood pressure levels. Seven studies [16–21,23] showed significant reductions ($p < 0.05$) in SBP and DBP levels in participants from the experimental group when compared to the control group; two of the studies [15,22] did not show much improvement when compared to the control group.

The meta-analysis showed a significant reduction in SBP (MD = −10.40, 95% CI −17.49 to −3.32, $p < 0.001$) and DBP (MD= −5.97, 95% CI −9.20 to −2.74, $p < 0.001$) levels (Figures 3 and 4).

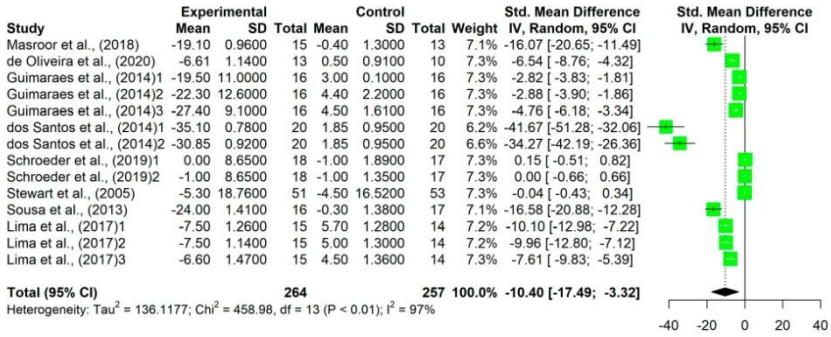


Figure 3. Forest plot comparing multicomponent training with supervision on changes in systolic blood pressure [15–18,20–23].

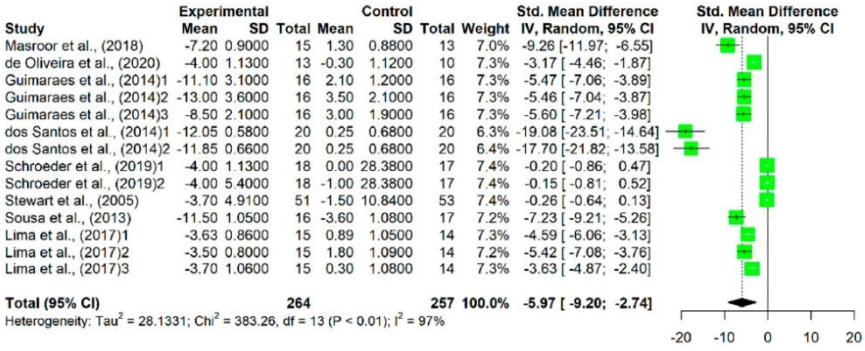


Figure 4. Forest plot comparing multicomponent training with supervision on changes in diastolic blood pressure [15–18,20–23].

The meta-analysis for SBP (Table 4) and DBP (Table 5) indicate that multicomponent training showed improvements independent of age and the weekly frequency and intensity of aerobic training. All program durations showed significant improvements in DBP and SBP; however, those with a duration longer than 14 weeks produced significantly greater improvements (SBP: MD = 0.36, $p = 0.043$, DBP: MD = 0.40, $p = 0.024$).

Similar results were observed for the duration of the training session in relation to SBP, with the most significant improvements observed for a duration of 30 min or longer. In relation to DBP, both protocols showed significant reductions, with no differences between them.

In the strength component, a work intensity of less than 75% of one repetition maximum (1 RM) (or equivalent) did not produce significant improvements in SBP though higher intensities did, with a significant difference observed between the two intensities used ($p = 0.013$). With respect to DBP, an intensity lower or higher than 75% of 1 RM produced significant improvements with a tendency towards significance, with no differences between the two. Any number of repetitions produced significant improvements in both SBP and DBP levels. However, a lower number of repetitions ($\leq$10) resulted in significantly greater improvements in SBP than a higher number of repetitions (>10) ($p = 0.005$).

The programmes that used aerobic work first and strength work second did not show a significant improvement in SBP values; those that applied the components in reverse did show a significant reduction (MD = −2.65; $p = 0.007$); however, the difference between groups was not significant. For DBP, significant improvements with no differences between them were found for both cases.

Table 4. Analysis of the effect of multicomponent training on SBP in patients with hypertension according to duration in weeks, weekly frequency, type of physical exercise programme applied, intensity, volume, and order of components.

	Authors	G	MD	95% CI	*p*	MD	95% CI	*p*
Age								
<65 years	Masroor et al. [21], de Oliveira et al. [23], Guimaraes et al. [18], dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Schroeder et al. [22]	6	−2.2	−3.63; −0.78	0.002	−0.17	−0.58; 0.23	0.400
≥65 years	Sousa et al. [16] and Lima et al. [20]	2	−1.06	−1.93; 0.2	0.016			
Weeks								
<14 weeks	Masroor et al. [21], de Oliveira et al. [23], Guimaraes et al. [18], Schroeder et al. [22], and Lima et al. [20]	5	−0.97	−1.74; 0.21	0.012	0.36	−0.01; 0.70	0.043
≥14 weeks	dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Sousa et al. [16]	3	−3.51	−5.74; −1.27	0.002			
Frequency								
3 days/weeks	de Oliveira et al. [23], Guimaraes et al. [18], dos Santos et al. [17], Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	6	−1.47	−2.53; −0.40	0.006	0.42	0.97; −0.12	0.130
>3 days/weeks	Masroor et al. [21]	1	−2.63	−3.63; −1.64	<0.001			
Intensity Aerobic Training								
≤75% HRR	Masroor et al. [21], Guimaraes et al. [18], dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Schroeder et al. [22]	5	−1.51	−4.26; −0.77	0.004	−0.05	−0.47; 0.37	0.819
>75% HRR	de Oliveira et al. [23] and Sousa et al. [16]	2	−1.15	−1.87; −0.43	0.001			
Duration Aerobic Training								
<30 min	de Oliveira et al. [23], dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Lima et al. [20]	4	−2.58	−4.61; −0.55	0.012	0.46	0.16; 0.76	0.002
≥30 min	Masroor et al. [21], Guimaraes et al. [18], Schroeder et al. [22], Stewart et al. [15], and Sousa et al. [16]	5	−5.25	−8.14; 2.35;	<0.001			
Intensity Strength Training								
≤75% 1 RM	Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	3	−0.69	−1.55; 0.16	0.112	0.56	0.12;1	0.013
>75% 1 RM	Masroor et al. [21] and dos Santos et al. [17]_1_TRT	2	−4.03	−6.86; −1.21	0.005			

Table 4. *Cont.*

	Authors	G	MD	95% CI	*p*	MD	95% CI	*p*
Repetitions Strength Training								
≤10	Masroor et al. [21] and dos Santos et al. [17]_1 TRT	2	−4.03	−6.86; −1.21	0.005	−0.61	−1.03; −0.18	0.005
>10	de Oliveira et al. [23], Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	4	−0.71	−1.33; −0.08	0.026			
Order Training Components								
Aerobic + Strength	Masroor et al. [21], de Oliveira et al. [23], and Schroeder et al. [22]	3	−1.10	−2.52; 0.33	0.131	0.22	−0.16; 0.59	0.256
Strength + Aerobic	Guimaraes et al. [18], dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Lima et al. [20]	4	−2.65	−4.59; −0.71	0.007			

MD: mean difference; HRR = heart rate reserve; CI: confidence interval; *p*: significance; MR: maximum repetition.

Table 5. Analysis of the effect of multicomponent training on DBP in patients with hypertension according to duration in weeks, weekly frequency, type of physical exercise programme applied, intensity, volume, and order of components.

	Authors	G	MD	95% CI	*p*	MD	95% CI	*p*
Age								
<65 years	Masroor et al. [21], de Oliveira et al. [23], Guimaraes et al. [18], dos Santos et al. [17]_1_TRT, dos Santos et al. [17]_2_ERT, and Schroeder et al. [22]	6	−1.79	−2.67; −0.91	<0.001	−0.20	−0.60; 0.2	0.326
≥65 years	Sousa et al. [16] and Lima et al. [20]	2	−0.97	−1.60; −0.34	0.002			
Weeks								
<14 weeks	Masroor et al. [21], de Oliveira et al. [23], Guimaraes et al. [18], Schroeder et al. [22], and Lima et al. [20]	5	−1.04	−1.55; 0.54	<0.001	0.40	0.75; 0.05	0.024
≥14 weeks	dos Santos et al. [17] _1_TRT, dos Santos et al. [17] _2_ERT, and Sousa et al. [16]	3	−2.51	−3.83; −1.18	<0.001			
Frequency								
3 days/weeks	de Oliveira et al. [23], Guimaraes et al. [18], dos Santos et al. [17] _1_TRT, Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	6	−1.46	−2.26; 0.66	<0.001	−0.08	0.47; −0.62	0.784
>3 days/weeks	Masroor et al. [21]	1	−1.17	−1.95; 0.39	0.003			

Table 5. *Cont.*

	Authors	G	MD	95% CI	*p*	MD	95% CI	*p*
Intensity Aerobic training								
≤75% HRR	Masroor et al. [21], de Oliveira et al. [23], Guimaraes et al. [18], dos Santos et al. [17] _1_TRT, dos Santos et al. [17] _2_ERT, and Schroeder et al. [22]	6	1.79	−2.67; 0.91	<0.001	−0.06	−0.58; 0.47	0.832
>75% HRR	Sousa et al. [16]	1	−1.3	−2.07; −0.53	<0.001			
Intensity Strength Training								
≤75% 1 RM	Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	3	−1.3	−2.06; −0.55	<0.001	0.21	0.64; −0.23	0.346
>75% 1 RM	Masroor et al. [21] and dos Santos et al. [17]_1_TRT	2	−2.35	−4.71; 0.01	0.050			
Duration Aerobic training								
<30 min	de Oliveira et al. [23], dos Santos et al. [17]_1_TRT, dos Santos et al. [17] _2_ERT, and Lima et al. [20]	4	−1.84	−3.28; −0.39	0.012	0.21	−0.09; 0.51;	0.173
≥30 min	Masroor et al. [21], Guimaraes et al. [18], Schroeder et al. [22], Stewart et al. [15], and Sousa et al. [16]	5	−3.05	−5.26; −0.85	0.006			
Repetitions Strength Training								
≤10	Masroor et al. [21] and dos Santos et al. [17]_1_TRT	2	−2.35	−4.71; 0.01	0.050	−0.26	0.15; −0.68	0.216
>10	de Oliveira et al. [23], Schroeder et al. [22], Sousa et al. [16], and Lima et al. [20]	4	−1.10	−1.76; 0.44	0.001			
Order Training Components								
Aerobic + Strength	Masroor et al. [21], de Oliveira et al. [23], and Schroeder et al. [22]	3	−1.21	−2.07; −0.36	0.005	0.16	−0.21; 0.53	0.398
Strength + Aerobic	Guimaraes et al. [18], dos Santos et al. [17] _1_TRT, dos Santos et al. [17] _2_ERT, and Lima et al. [20]	4	−1.95	−3.27; −0.64	0.003			

MD: mean difference; HRR = heart rate reserve; CI: confidence interval; *p*: significance; MR = maximum repetition.

4. Discussion

The main objective of the present study was to determine the effects of multicomponent training programmes on the SBP and DBP levels of adults with hypertension. The results confirm the first hypothesis formulated: multicomponent training will be effective in reducing systolic and diastolic hypertension levels in subjects with hypertension. The results showed that a multicomponent training programme achieved significant reductions in SBP and DBP levels in adults with hypertension, with these changes being significantly different from a control group. Individually, the works by Masroor et al. [21], dos Santos et al. [17], de Oliveira et al. [23], Guimaraes et al. [18], Sousa et al. [16], and Lima et al. [20] showed significant reductions in both SBP and DBP values post intervention with multicomponent training programmes. The study by Dos Santos et al. [17] showed the greatest effects on SBP and DBP levels, and the study by Schroeder et al. [22] only showed improvements in peripheral and central SBP levels and not in peripheral and central DBP levels. This difference may be because the latter study included only subjects with uncontrolled mild hypertension compared to the inclusion of subjects with monitored grades one and two hypertension in the other studies.

Our findings are in line with those from other systematic reviews and meta-analyses [12–14,34]. The works by Corso et al. [12], Herrod et al. [13], and Pescatello et al. [14] described significant reductions in SBP and DBP levels with multicomponent training. It should be noted that in the study by Herrod et al. [13], the intervention did not provide benefits that were any greater than single-mode training. In the review by Cornelissen et al. [34], only significant reductions in DBP levels were obtained with multicomponent training, without changes observed in SBP values. On the other hand, one of the most recent reviews, written by Saco-Ledo et al. [35], did not describe significant benefits on ambulatory blood pressure levels, specifying that significant benefits were only obtained with aerobic training programmes. However, the authors only included three studies in their systematic review that used multicomponent training, and one of them worked with people with mild hypertension, so the result may not be significant. The authors themselves indicated that more studies were needed for considering their results.

In this sense, multicomponent training as a physical activity programme is effective in playing an important role not only in primary but also in secondary cardiovascular prevention. In this regard, the effects of physical activity programmes on the metabolic environment and systemic chronic inflammation, as well as adaptations at the vascular and cardiac tissue levels, have been described [36,37]. As in the studies previously mentioned, those included in the present systematic review and meta-analysis were highly heterogeneous in terms of the design of the multicomponent training programmes, suggesting that this may have an influence on the outcome of the SBP and DBP responses [38,39], which will be discussed below.

These reductions in SBP and DBP can also be affected by drug treatment. In addition to commencing drug treatment, the patient with hypertension should make lifestyle changes, such as including regular physical exercise [40,41]. The studies by Sousa et al. [16], dos Santos et al. [17], Guimaraes et al. [18], Lima et al. [20], Masroor et al. [21], and de Oliveira et al. [23] included adults with monitored hypertension as the inclusion criteria. The participants in both the experimental and control groups had some pharmacological treatment that they continued to maintain during the study. After the completion of the multicomponent training interventions, the studies showed significant reductions in SBP and DBP levels, and these reductions differed from changes in the control group, who did not take part in the training programmes. However, the participants in the studies by Stewart et al. [15] and Schroeder et al. [22] had mild hypertension without pharmacological treatment as an inclusion criterion. The first [15] showed significant reductions in SBP and DBP; however, these did not differ from changes in the control group, and the second [22] showed a reduction in SBP, which was significantly different compared to the control group but not in DBP. This could be due to the fact that multicomponent training may be more

effective for higher levels of hypertension, and the differential results could also be due to the differences in the programmes implemented, as will be discussed below.

The second objective of the present study was to identify the optimal dosage of multicomponent training for managing hypertension in adults. The results confirm the second hypothesis: the multicomponent training protocol that will show the greatest benefits for blood pressure will be one that applies moderate to vigorous intensities in cardiovascular work and moderate to high intensities in strength training. Age is one of the risk factors that influences blood pressure levels, with the risk of hypertension increasing from the ages of 60–65 years old [42]. The present meta-analysis shows that multicomponent training produced significant improvements in SBP and DBP regardless of age when comparing studies that included a sample younger than 65 years old [17,18,21–23] with studies that included a sample older than 65 [16,20]. These positive results are due to the fact that regular physical exercise can prevent or reverse pathologies associated with aging, as is the case with hypertension and as reflected in studies such as the one by Marcos-Pardo [9] in its multi-domain intervention programme Healthy-Age.

Regarding the duration of the interventions, the results of the meta-analysis showed significant reductions in SBP and DBP levels with multicomponent training regardless of the duration of the programme. Of note, interventions lasting longer or equal to 14 weeks resulted in greater reductions in blood pressure levels. Acute adaptations to exercise occur from the start, with reductions of 10–20 mm Hg in SBP after the end of the training session, with these effects lasting up to 22 h. If exercise is maintained regularly over time, these adaptations will become increasingly larger and chronic, with reductions of up to 10 mm Hg in SBP and 8 mm Hg in DBP [43]. Training programmes aimed at improving and managing hypertension should be considered as lifelong strategies to maintain these adaptations.

Regarding the frequency of the multicomponent training programmes, no significant differences were observed. The result of the meta-analysis indicated that reductions in SBP and DBP improved independently of the number of training days, with three days/week being the minimum frequency applied in the included studies. The exercise recommendations for hypertension from the American College of Sports Medicine and the latest hypertension clinical guidelines indicate the same frequency as the results obtained in this meta-analysis, with 3 days/week being the minimum training frequency recommended [3,44].

In relation to aerobic training, all the groups obtained significant reductions in SBP and DBP irrespective of work volume or intensity. However, the protocols that applied $\geq$30 min of work were shown to be more effective in reducing SBP. Regarding the minimum aerobic exercise time for improving hypertension, the main cardiology clinical guidelines state a minimum of 30 min per day, a length of time associated with reductions of 7 mm Hg for SBP and 5 mm Hg for DBP, with these guidelines in line with the results obtained in this meta-analysis.

In the protocols utilized for strength work, the studies that used a lower number of repetitions also showed a higher percentage of repetition maximum. The meta-analysis revealed that although both groups showed improvements, performing less than or equal to 10 repetitions produced greater reductions in SBP. In relation to the percentage of 1 RM, only work higher than 75% of 1 RM produced improvements in this variable. The DBP response was not different between protocols that applied intensities lower than 75% of 1 RM than higher ones, nor between protocols that performed more than 10 repetitions versus those that performed fewer repetitions. In this sense, it follows that a higher-volume and lower-intensity strength work protocol could have a greater influence on blood pressure in subjects with hypertension. Training programmes aimed at improving strength at low–moderate work intensities provide many benefits for the adult population, with this being an effective stimulus for improving blood pressure levels [45]. The exercise recommendations for subjects with hypertension refer to the practice of 150–300 min of aerobic exercise per week at a moderate–vigorous intensity, including 2–3 days of strength exercise per week, without specifying intensities, series, or repetitions, making it difficult to compare the findings from this meta-analysis [3].

The present meta-analysis did not show significant differences with respect to the order of the exercise components, although the changes in the order were only significant for the group that first performed strength exercises and then aerobics [17,18,20]. Some studies, such as those by Eklund et al. [46], Schumann et al. [47], or Wilhelm et al. [48], can explain these results. In their work, with different types of populations, sedentary women, sedentary older adults, and active young men, it was observed that the order of the components in multicomponent training programmes did not affect the adaptations of each modality.

Strengths and limitations:

The main limitation of this systematic review and meta-analysis is the small number of RCTs that currently exist, the heterogeneity of the population included (sex and age), the heterogeneity of the protocols, the types of aerobic and strength training exercises, and the small sample sizes in some studies. These aspects limit the comparisons between the different intervention groups and indicate the need for new studies to provide new data that allows for the generalisation of results.

However, the studies analysed herein also had strengths, among which we must underline that they obtained scores between 8 and 10 on the PEDRO scale, a ranking considered "high quality" [28].

5. Conclusions

The results of this study indicate that multicomponent training programmes significantly improved the SBP and DBP levels of adults with hypertension. The greatest benefits were found in programmes lasting longer than 14 weeks with a frequency of at least three sessions per week and sessions lasting approximately 60 min. The intensity of aerobic training should be around 75% of the reserve HR, and the intensity of strength training should be greater than 75% of 1 RM, with 10 repetitions or less per set. This research provides relevant information for professionals who prescribe physical activity to subjects with hypertension, providing key guidelines for its implementation. In this regard, there are several future areas for research in this field. It is necessary to investigate if there are differences in the results of the application of two protocols with training that apply the different components in different sessions or in the same session. It is also considered relevant to investigate the influence of the type of activity during cardiovascular work.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/sports11060115/s1, Table S1: Search strategy. Search strategy used in each database is detailed.

Author Contributions: Conceptualization, I.L.-R. and N.G.-G.; methodology, I.L.-R. and N.G.-G.; software, I.L.-R. and N.G.-G.; validation, I.L.-R. and N.G.-G.; formal analysis, N.G.-G.; investigation, I.L.-R. and N.G.-G.; resources, I.L.-R.; data curation, I.L.-R. and N.G.-G.; writing—original draft preparation, I.L.-R. and N.G.-G.; writing—review and editing, I.L.-R., M.D.M., F.L., and N.G.-G.; visualization, I.L.-R., M.D.M., F.L. and N.G.-G.; supervision, N.G.-G. All authors have read and agreed to the published version of the manuscript.

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References

1. Stanaway, J.D.; Afshin, A.; Gakidou, E.; Lim, S.S.; Abate, D.; Abate, K.H.; Abbafati, C.; Abbasi, N.; Abbastabar, H.; Abd-Allah, F.; et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **2018**, *392*, 1923–1994. [CrossRef]
2. Roth, G.A.; Abate, D.; Abate, K.H.; Abay, S.M.; Abbafati, C.; Abbasi, N.; Abbastabar, H.; Abd-Allah, F.; Abdela, J.; Abdelalim, A.; et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980-2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **2018**, *392*, 1736–1788. [CrossRef] [PubMed]
3. Unger, T.; Borghi, C.; Charchar, F.; Khan, N.A.; Poulter, N.R.; Prabhakaran, D.; Ramirez, A.; Schlaich, M.; Stergiou, G.S.; Tomaszewski, M.; et al. 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension* **2020**, *75*, 1334–1357. [CrossRef] [PubMed]
4. Gómez, J.F.; Camacho, P.A.; López-López, J.; López-Jaramillo, P. Control y tratamiento de la hipertensión arterial: Programa 20-20. *Rev. Colomb. De Cardiol.* **2019**, *26*, 99–106. [CrossRef]
5. Bull, F.C.; Al-Ansari, S.S.; Biddle, S.; Borodulin, K.; Buman, M.P.; Cardon, G.; Carty, C.; Chaput, J.P.; Chastin, S.; Chou, R.; et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* **2020**, *54*, 1451–1462. [CrossRef]
6. Hanssen, H.; Boardman, H.; Deiseroth, A.; Moholdt, T.; Simonenko, M.; Kränkel, N.; Niebauer, J.; Tiberi, M.; Abreu, A.; Solberg, E.E.; et al. Personalized exercise prescription in the prevention and treatment of arterial hypertension: A Consensus Document from the European Association of Preventive Cardiology (EAPC) and the ESC Council on Hypertension. *Eur. J. Prev. Cardiol.* **2021**, *29*, 205–215. [CrossRef]
7. Rossi, F.E.; Fortaleza, A.C.; Neves, L.M.; Buonani, C.; Picolo, M.R.; Diniz, T.A.; Kalva-Filho, C.A.; Papoti, M.; Lira, F.S.; Freitas Junior, I.F. Combined Training (Aerobic Plus Strength) Potentiates a Reduction in Body Fat but Demonstrates No Difference on the Lipid Profile in Postmenopausal Women When Compared With Aerobic Training With a Similar Training Load. *J. Strength Cond. Res.* **2016**, *30*, 226–234. [CrossRef]
8. Dent, E.; Morley, J.E.; Cruz-Jentoft, A.J.; Woodhouse, L.; Rodríguez-Mañas, L.; Fried, L.P.; Woo, J.; Aprahamian, I.; Sanford, A.; Lundy, J.; et al. Physical Frailty: ICFSR International Clinical Practice Guidelines for Identification and Management. *J. Nutr. Health Aging* **2019**, *23*, 771–787. [CrossRef]
9. Pardo, P.J.M.; Gálvez, N.G.; Cristobal, R.V.; Romero, L.S.; Vivancos, A.L.; Díaz, D.V.; García, G.M.G.; González, J.G.P.; Cornejo, I.E.; Pavón, D.J. Programa de Intervención Multidominio Healthy-Age: Recomendaciones para un envejecimiento saludable: Porla red Healthy-Age. *Cult. Cienc. Y Deporte* **2021**, *16*, 311–320.
10. Li, Y.; Hanssen, H.; Cordes, M.; Rossmeissl, A.; Endes, S.; Schmidt-Trucksäss, A. Aerobic, resistance and combined exercise training on arterial stiffness in normotensive and hypertensive adults: A review. *Eur. J. Sport Sci.* **2015**, *15*, 443–457. [CrossRef]
11. Nelson, M.E.; Rejeski, W.J.; Blair, S.N.; Duncan, P.W.; Judge, J.O.; King, A.C.; Macera, C.A.; Castaneda-Sceppa, C. Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Med. Sci. Sports Exerc.* **2007**, *39*, 1435–1445. [CrossRef]
12. Corso, L.M.; Macdonald, H.V.; Johnson, B.T.; Farinatti, P.; Livingston, J.; Zaleski, A.L.; Blanchard, A.; Pescatello, L.S. Is Concurrent Training Efficacious Antihypertensive Therapy? A Meta-analysis. *Med. Sci. Sports Exerc.* **2016**, *48*, 2398–2406. [CrossRef]
13. Herrod, P.J.J.; Doleman, B.; Blackwell, J.E.M.; O'Boyle, F.; Williams, J.P.; Lund, J.N.; Phillips, B.E. Exercise and other nonpharmacological strategies to reduce blood pressure in older adults: A systematic review and meta-analysis. *J. Am. Soc. Hypertens.* **2018**, *12*, 248–267. [CrossRef]
14. Pescatello, L.S.; Buchner, D.M.; Jakicic, J.M.; Powell, K.E.; Kraus, W.E.; Bloodgood, B.; Campbell, W.W.; Dietz, S.; Dipietro, L.; George, S.M.; et al. Physical Activity to Prevent and Treat Hypertension: A Systematic Review. *Med. Sci. Sports Exerc.* **2019**, *51*, 1314–1323. [CrossRef]
15. Stewart, K.J.; Bacher, A.C.; Turner, K.L.; Fleg, J.L.; Hees, P.S.; Shapiro, E.P.; Tayback, M.; Ouyang, P. Effect of exercise on blood pressure in older persons: A randomized controlled trial. *Arch. Intern. Med.* **2005**, *165*, 756–762. [CrossRef]
16. Sousa, N.; Mendes, R.; Abrantes, C.; Sampaio, J.; Oliveira, J. A randomized 9-month study of blood pressure and body fat responses to aerobic training versus combined aerobic and resistance training in older men. *Exp. Gerontol.* **2013**, *48*, 727–733. [CrossRef]
17. Dos Santos, E.S.; Asano, R.Y.; Filho, I.G.; Lopes, N.L.; Panelli, P.; Nascimento Dda, C.; Collier, S.R.; Prestes, J. Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: A randomized controlled trial. *J. Strength Cond. Res.* **2014**, *28*, 3073–3084. [CrossRef]
18. Guimaraes, G.V.; de Barros Cruz, L.G.; Fernandes-Silva, M.M.; Dorea, E.L.; Bocchi, E.A. Heated water-based exercise training reduces 24-hour ambulatory blood pressure levels in resistant hypertensive patients: A randomized controlled trial (HEx trial). *Int. J. Cardiol.* **2014**, *172*, 434–441. [CrossRef]
19. Son, W.M.; Sung, K.D.; Cho, J.M.; Park, S.Y. Combined exercise reduces arterial stiffness, blood pressure, and blood markers for cardiovascular risk in postmenopausal women with hypertension. *Menopause* **2016**, *24*, 262–268. [CrossRef]
20. Lima, L.G.; Bonardi, J.T.M.; Campos, G.O.; Bertani, R.F.; Scher, L.M.L.; Moriguti, J.C.; Ferriolli, E.; Lima, N.K.C. Combined aerobic and resistance training: Are there additional benefits for older hypertensive adults? *Clinics* **2017**, *72*, 363–369. [CrossRef]

21. Masroor, S.; Bhati, P.; Verma, S.; Khan, M.; Hussain, M.E. Heart Rate Variability following Combined Aerobic and Resistance Training in Sedentary Hypertensive Women: A Randomised Control Trial. *Indian Heart J.* **2018**, *70* (Suppl. S3), S28–S35. [CrossRef] [PubMed]
22. Schroeder, E.C.; Franke, W.D.; Sharp, R.L.; Lee, D.C. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PLoS ONE* **2019**, *14*, e0210292. [CrossRef] [PubMed]
23. De Oliveira, S.N.; Pereira Moro, A.R.; Polito, M.D.; Helena de Jesus, J.; de Souza Bezerra, E. Effects of Concurrent Training with Elastic Tubes in Hypertensive Patients: A Blind Controlled Randomized Clinical Trial. *Exp. Aging Res.* **2019**, *46*, 68–82. [CrossRef] [PubMed]
24. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* **2021**, *372*, n71. [CrossRef] [PubMed]
25. Higgins, J.P.T.; Green, S. (Eds.) *Cochrane Handbook for Systematic Reviews of Interventions*; Version 5.1.0; The Cochrane Collaboration: London, UK, 2011; Available online: https://www.cochrane-handbook.org (accessed on 1 February 2021).
26. Egger, M.; Davey Smith, G.; Schneider, M.; Minder, C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* **1997**, *315*, 629–634. [CrossRef]
27. Rosenthal, R. The file drawer problem and tolerance for null results. *Psychol. Bull.* **1979**, *86*, 638–641. [CrossRef]
28. De Morton, N.A. The PEDro scale is a valid measure of the methodological quality of clinical trials: A demographic study. *Aust. J. Physiother.* **2009**, *55*, 129–133. [CrossRef]
29. McHugh, M.L. Interrater reliability: The kappa statistic. *Biochem. Med.* **2012**, *22*, 276–282. [CrossRef]
30. Sterne, J.A.; Sutton, A.J.; Ioannidis, J.P.; Terrin, N.; Jones, D.R.; Lau, J.; Carpenter, J.; Rücker, G.; Harbord, R.M.; Schmid, C.H.; et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ* **2011**, *343*, d4002. [CrossRef]
31. Higgins, J.P.; Thomas, J.; Chandler, J.; Cumpston, M.; Li, T.; Page, M.J.; Welch, V.A. *Cochrane Handbook for Systematic Reviews of Interventions*; John Wiley & Sons: Hoboken, NJ, USA, 2019.
32. Higgins, J.P.; Thompson, S.G. Controlling the risk of spurious findings from meta-regression. *Stat. Med.* **2004**, *23*, 1663–1682. [CrossRef]
33. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: New York, NY, USA, 1988.
34. Cornelissen, V.A.; Smart, N.A. Exercise training for blood pressure: A systematic review and meta-analysis. *J. Am. Heart Assoc.* **2013**, *2*, e004473. [CrossRef]
35. Saco-Ledo, G.; Valenzuela, P.L.; Ruiz-Hurtado, G.; Ruilope, L.M.; Lucia, A. Exercise Reduces Ambulatory Blood Pressure in Patients With Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J. Am. Heart Assoc.* **2020**, *9*, e018487. [CrossRef]
36. Valenzuela, P.L.; Ruilope, L.M.; Santos-Lozano, A.; Wilhelm, M.; Kränkel, N.; Fiuza-Luces, C.; Lucia, A. Exercise benefits in cardiovascular diseases: From mechanisms to clinical implementation. *Eur. Heart J.* **2023**, *44*, 1874–1889. [CrossRef]
37. Bullard, T.; Ji, M.; An, R.; Trinh, L.; Mackenzie, M.; Mullen, S.P. A systematic review and meta-analysis of adherence to physical activity interventions among three chronic conditions: Cancer, cardiovascular disease, and diabetes. *BMC Public Health* **2019**, *19*, 636. [CrossRef]
38. Spiering, B.A.; Kraemer, W.J.; Anderson, J.M.; Armstrong, L.E.; Nindl, B.C.; Volek, J.S.; Maresh, C.M. Resistance exercise biology: Manipulation of resistance exercise programme variables determines the responses of cellular and molecular signalling pathways. *Sports Med.* **2008**, *38*, 527–540. [CrossRef]
39. Taipale, R.S.; Häkkinen, K. Acute hormonal and force responses to combined strength and endurance loadings in men and women: The "order effect". *PLoS ONE* **2013**, *8*, e55051. [CrossRef]
40. Williams, B.; Mancia, G.; Spiering, W.; Agabiti Rosei, E.; Azizi, M.; Burnier, M.; Clement, D.L.; Coca, A.; de Simone, G.; Dominiczak, A.; et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension: The Task Force for the management of arterial hypertension of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH). *Eur. Heart J.* **2018**, *39*, 3021–3104. [CrossRef]
41. Pescatello, L.S.; Franklin, B.A.; Fagard, R.; Farquhar, W.B.; Kelley, G.A.; Ray, C.A. American College of Sports Medicine position stand. Exercise and hypertension. *Med. Sci. Sports Exerc.* **2004**, *36*, 533–553. [CrossRef]
42. Anandita, M.; Mehta, A.; Yang, E.; Parapid, B. *Older Adults and Hypertension: Beyond the 2017 Guideline for Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults*; American College of Cardiology: Washington, DC, USA, 2020; Volume 26.
43. Pedersen, B.K.; Saltin, B. Exercise as medicine—Evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scand. J. Med. Sci. Sports* **2015**, *25* (Suppl. S3), 1–72. [CrossRef]
44. Zaleski, A. *Exercise for the Prevention and Treatment of Hypertension–Implications and Application*; American College of Sports Medicine: Indianapolis, IN, USA, 2019.
45. Zhang, Y.; Zhang, Y.J.; Zhang, H.W.; Ye, W.B.; Korivi, M. Low-to-Moderate-Intensity Resistance Exercise Is More Effective than High-Intensity at Improving Endothelial Function in Adults: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6723. [CrossRef]

46. Eklund, D.; Schumann, M.; Kraemer, W.J.; Izquierdo, M.; Taipale, R.S.; Häkkinen, K. Acute Endocrine and Force Responses and Long-Term Adaptations to Same-Session Combined Strength and Endurance Training in Women. *J. Strength Cond. Res.* **2016**, *30*, 164–175. [CrossRef] [PubMed]
47. Schumann, M.; Küüsmaa, M.; Newton, R.U.; Sirparanta, A.I.; Syväoja, H.; Häkkinen, A.; Häkkinen, K. Fitness and lean mass increases during combined training independent of loading order. *Med. Sci. Sports Exerc.* **2014**, *46*, 1758–1768. [CrossRef] [PubMed]
48. Wilhelm, E.N.; Rech, A.; Minozzo, F.; Botton, C.E.; Radaelli, R.; Teixeira, B.C.; Reischak-Oliveira, A.; Pinto, R.S. Concurrent strength and endurance training exercise sequence does not affect neuromuscular adaptations in older men. *Exp. Gerontol.* **2014**, *60*, 207–214. [CrossRef] [PubMed]

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ANEXO 15. Estudio 2. Concurrent training based on an individual load-velocity ratio assessment as a better alternative to continuous endurance training to improve hypertension.

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Concurrent training based on an individual load-velocity ratio assessment as a better alternative to continuous endurance training to improve hypertension

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Hypertension remains a major global public health problem as the leading modifiable risk factor for cardiovascular death worldwide, responsible for more than 10 million deaths per year. The aim of the present study was to compare the effect of strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training, and endurance training on blood and metabolic biomarkers, body composition and physical fitness in adults with hypertension. A randomised, single-blind, 12-week, prospective clinical trial was conducted. The study included 75 volunteers with an average age of 54 years, all of whom were hypertensive and sedentary. The sample was randomly assigned into three groups, strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training, endurance training alone group, and a control group. The concurrent training group obtained greater reductions in SBP, DBP and MAP than the endurance training group, up to 12.8 mmHg, 6.8 mmHg and 8.6 mmHg respectively. The findings of the present study indicate that performing strength training, based on an individual load-velocity ratio assessment, concurrent with endurance training 2 days per week for 12 weeks, leads to improvements in metabolic and blood biomarkers, body composition, and physical fitness, of adults with hypertension, with these adaptations being superior to those produced by endurance training alone.

Keywords High blood pressure, Exercise, Combined training, Strength training, Velocity of execution, Endurance

Presently, hypertension remains the main modifiable risk factor worldwide for premature cardiovascular deaths[1]. Large epidemiological studies have shown an inverse relationship between the incidence of hypertension and exercise[2,3], understood as the set of ordered, structured and systematised movements aimed at improving health or physical condition. The most important clinical guidelines recommend exercise for subjects with hypertension, giving priority to endurance training[4–6]. The effects of endurance training on hypertension have been studied and are well described in the literature, showing reductions in the range of -4.9 to -12 millimetres of mercury (mmHg) for systolic blood pressure (SBP) and – 3.4 to -5.8 mmHg for diastolic blood pressure (DBP)[7,8]. Some guidelines recommend incorporating strength training as well[4], but few individuals comply with their prescription in depth[8]. Strength training has shown improvements ranging from – 3.0 to -4.7mmHg for SBP and – 3.2 to -3.8mmHg for DBP[7,8]. In addition to these guidelines, the available evidence shows that concurrent training, understood as training that combines strength and endurance work in the same training session, has also shown great benefits on health, specifically on hypertension[9–11]. Different controlled trials[12–14] showed significant reductions in SBP and DBP levels with concurrent programme interventions[9,15–17].

However, there are large differences among the protocols applied (frequency, intensity, volume, recovery time and characteristics, selection, organisation and distribution of exercises) in the different studies conducted[3,9].

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Despite scientific evidence showing improvements in blood pressure levels and other metabolic markers with combined or concurrent training, further research is needed to gain a more specific understanding of the dose-response relationship of this type of training and to standardize such training programs[9,18,19]. Recent studies indicate that due to the heterogeneity of research quality and heterogeneity in research protocols, further research is needed to determine the effect of these types of programs. This study is the first to apply a concurrent training program, considering the loss of running speed when prescribing repetitions[9,20]. One of the main problems is the lack of precision in the quantification of the work stimulus in strength training, which makes it very difficult to establish a dose-response relationship, as it is not known whether the intensity with which the participants trained was the same as that programmed and applied, as well as not knowing the degree of fatigue reached by each participant in each set or training session. A major difficulty in designing strength training programmes is how to accurately quantify and control the workload in order to obtain the greatest health and fitness benefits[21]. In order to address this problem, the focus has been on the velocity of execution[22,23]. This form of effort programming has brought about a paradigm shift in the control of strength training[21,23,24]. Despite all of the research on strength training through speed of execution and its positive results as a tool for training programming in the young population and athletes[24,25], cancer survivors[26], multiple sclerosis and older adults[27], there is still a gap in the health field in relation to the design of exercise programmes with this methodology, and especially in subjects with hypertension. Training methods such as velocity-based training should be prioritized over the repetitions until failure method to minimize the risk of overexertion[28,29].

Therefore, the aim of the present study was to compare the effect of strength training, based on an individual load-velocity ratio assessment, combined with endurance training, and endurance training alone, on blood and metabolic biomarkers, body composition and physical fitness in adults with hypertension, by actually knowing the exercise dose applied in the training.

Results

Table 1 shows the training monitoring results (HR, %HRmax, and RPE) for each group in each week. Participants showed a HR average of 113.74± 11, a %HR max of 145.14± 13.17, and an RPE of 3.16± 0.92; there were no significant differences between the intervention groups. Tables 2 and 3 show the pre-post intervention results for EG1, EG2 and CG. The group * time interaction is also presented.

EG1 and EG2 showed significant improvements in SBP (mmHg), DBP (mmHg), mean arterial pressure (MAP) (mmHg), pulse pressure (PP) (mmHg), rate pressure product (RPP), resting heart rate (RHR), lean mass (kg), body fat (%), waist circumference (cm), glucose (mg/dl), right handgrip (kg), left handgrip (kg), upper limb MPV (m/s 50%), %RM UB, lower limb MPV (m/s 60%), and VO_2peak (ml/kg/min). These changes were significantly different from the CG changes. Specifically, EG1 showed greater improvements of up to -12.8 mmHg in SBP, -6.8 mmHg in DBP and – 8.6 in MAP over EG2. Improvements in PP, waist circumference, upper limb PWV (m/s 50%), 1RM (LB), lower limb PWV (m/s 60%) and VO_2peak (ml/kg/min) were also greater in EG1 than in EG2.

Discussion

The aim of this present study was to compare the effect of concurrent training, based on an individual load-velocity ratio assessment, and endurance training alone on blood and metabolic biomarkers, body composition and fitness of adults with hypertension. One of the main findings of this study was that both groups, concurrent training and endurance training, showed improvements in blood biomarkers, reducing SBP, DBP, MAP, PP, RPP and RHR. However, the concurrent training group obtained greater reductions in SBP, DBP and MAP than the endurance training group, up to -12.8 mmHg, -6.8 mmHg and – 8.6 mmHg respectively. The same dynamics was observed in PP. The results obtained in the present study, on the reduction of blood pressure levels, were significantly greater than those obtained in previous studies with this same training modality, despite the fact that the training frequency was lower. These improvements may be due to different mechanisms such as endothelium-

	EG1			EG2		
	HR average	%HR max	RPE	HR average	%HR max	RPE
Week 1	118.88 ± 15.88	66.56	3.20 ± 1.41	117.75 ± 13.61	66.75	3.21 ± 1.22
Week 2	116.32 ± 12.58	65.60	2.88 ± 1.33	118.25 ± 12.02	67.25	3.21 ± 0.98
Week 3	118.12 ± 11.50	66.84	3.20 ± 1.08	118.21 ± 14.02	67.25	3.33 ± 1.09
Week 4	115.60 ± 13.24	65.32	2.84 ± 1.18	118.21 ± 13.28	67.21	3.17 ± 1.20
Week 5	115.92 ± 14.75	65.68	3.00 ± 1.26	118.83 ± 13.35	67.50	3.37 ± 1.06
Week 6	115.32 ± 14.18	65.20	2.96 ± 0.93	117.21 ± 11.62	66.58	3.12 ± 0.95
Week 7	115.84 ± 12.72	65.12	2.84 ± 1.03	119.79 ± 13.38	68.13	3.46 ± 1.18
Week 8	116.80 ± 15.57	65.72	3.16 ± 1.28	119.17 ± 11.37	67.75	3.21 ± 1.18
Week 9	119.36 ± 13.39	67.16	3.16 ± 1.14	121.33 ± 11.62	68.75	3.38 ± 1.31
Week 10	117.32 ± 12.56	66.36	3.08 ± 1.08	118.50 ± 10.47	67.29	3.08 ± 0.97
Week 11	120.00 ± 16.03	67.80	3.52 ± 1.33	122.04 ± 11.72	69.42	3.54 ± 1.22
Week 12	113.96 ± 13.25	64.56	2.84 ± 0.94	117.79 ± 10.89	67.00	3.21 ± 1.02

Table 1. Training monitoring results.

Outcome	Group	Pre-test (M ± ED)	Post-test (M ± ED)	Difference post-pre (M ± ED)	p	95% CI (Mpost-Mpre)	Group*time interaction		
							F	Sig	ES
SBP (mmHg)	EG1	142.441 ± 7.53	121.76 ± 8.52	− 21.68 ± 1.43**##	<0.001	− 24.52; − 18.84	52.00	<0.001	0.59
	EG2	144.12 ± 8.81	135.24 ± 8.98	− 8.88 ± 1.43**	<0.001	− 11.72; − 6.04			
	CG	147.92 ± 11.84	146.56 ± 11.53	− 1.36 ± 1.43	0.343	− 4.20; 1.48			
DBP (mmHg)	EG1	88.28 ± 5.73	74.36 ± 5.10	− 13.92 ± 1.08**##	<0.001	− 16.067; − 11.773	26.92	<0.001	0.43
	EG2	89.68 ± 6.95	82.56 ± 6.26	− 7.12 ± 1.08*	<0.001	− 9.267; − 4.973			
	CG	92.16 ± 7.28	89.32 ± 6.95	− 2.84 ± 1.08	0.01	− 4.987; − 0.693			
MAP (mmHg)	EG1	106.52 ± 5.28	90.12 ± 5.34	− 16.40 ± 1.00**##	<0.001	− 18.393; − 14.407	50.50	<0.001	0.58
	EG2	107.84 ± 6.06	100.12 ± 6.37	− 7.72 ± 1.00**	<0.001	− 9.713; − 5.727			
	CG	110.60 ± 7.25	108.28 ± 7.80	− 2.32 ± 1.00	0.023	− 4.313; − 0.327			
PP (mmHg)	EG1	55.16 ± 7.49	47.40 ± 7.68	− 7.76 ± 1.45**#	<0.001	− 10.642; − 4.878	10.43	<0.001	0.23
	EG2	54.44 ± 10.08	52.68 ± 7.17	− 1.76 ± 1.45	0.227	− 4.642; 1.122			
	CG	55.76 ± 11.32	57.20 ± 8.52	1.44 ± 1.45	0.323	− 1.442; 4.322			
RPP	EG1	11254.00 ± 1735.96	8507.64 ± 1309.88	− 2746.36 ± 251.20**##	<0.001	− 3247.117; − 2245.603	30.94	<0.001	0.46
	EG2	11321.60 ± 1442.08	9957.36 ± 1358.10	− 1364.24 ± 251.20**	<0.001	− 1864.997; − 863.483			
	CG	11827.56 ± 1474.97	11875.68 ± 1132.23	48.12 ± 251.20	0.849	− 452.637; 548.877			
RHR	EG1	78.40 ± 11.06	69.72 ± 8.49	− 8.68 ± 1.68**	<0.001	− 12.032; − 5.328	8.99	<0.001	0.20
	EG2	78.80 ± 11.03	73.72 ± 9.35	− 5.08 ± 1.68*	0.003	− 8.432; − 1728			
	CG	80.00 ± 8.23	81.28 ± 8.07	1.28 ± 1.68	0.449	− 2.072; 4.632			
BMI (kg/m²)	EG1	27.43 ± 4.88	27.26 ± 4.57	− 0.18 ± 0.16	0.275	− 0.495; 0.143	0.27	0.76	0.01
	EG2	32.75 ± 5.09	32.56 ± 5.06	− 0.19 ± 0.16	0.234	− 0.511; 0.127			
	CG	31.91 ± 5.00	31.87 ± 5.10	− 0.04 ± 0.16	0.803	− 0.359; 0.279			
LBM (Kg)	EG1	28.99 ± 6.74	29.57 ± 6.77	0.58 ± 0.15**	<0.001	0.279; 0.881	7.55	<0.001	0.17
	EG2	30.84 ± 6.80	31.35 ± 6.81	0.51 ± 0.15**	<0.001	0.207; 0.809			
	CG	30.56 ± 5.98	30.39 ± 5.92	− 0.17 ± 0.15	0.258	− 0.473; 0.129			
BFP (%)	EG1	32.63 ± 10.27	31.56 ± 9.76	− 1.07 ± 0.34*	0.002	− 1.739; − 0.405	4.41	0.02	0.11
	EG2	39.43 ± 8.04	38.47 ± 8.14	− 0.96 ± 0.34*	0.005	− 1.631; − 0.297			
	CG	37.70 ± 8.45	37.89 ± 8.70	0.20 ± 0.34	0.56	− 0.471; 0.863			
VF (cm²)	EG1	125.19 ± 58.84	119.75 ± 54.33	− 5.44 ± 2.13*	0.013	− 9.68; − 1.208	2.78	0.07	0.07
	EG2	183.40 ± 58.34	178.28 ± 58.00	− 5.12 ± 2.13*	0.018	− 9.36; − 0.888			
	CG	165.26 ± 54.59	166.10 ± 55.82	0.85 ± 2.13	0.691	− 3.388; 5.084			
Waist circumference (cm)	EG1	98.76 ± 10.54	92.16 ± 10.59	− 6.60 ± 0.84**#	<0.001	− 8.265; − 4.935	19.25	<0.001	0.35
	EG2	110.48 ± 13.13	107.28 ± 15.12	− 3.20 ± 0.84**	<0.001	− 4.865; − 1.535			
	CG	105.80 ± 12.33	106.52 ± 12.65	0.72 ± 0.84	0.391	− 0.945; 2.385			

Table 2. Effect of combined training and endurance training on blood biomarker and body composition. SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MAP: Mean Arterial Pressure; PP: Pulse Pressure: RPP: Rate Pressure Product; RHR: Resting Heart Rate; BMI: Body Mass Index; LBM: Lean Body Mass; BFP: Body Fat Percentage; VF: Visceral Fat. *Significantly different from CG value at the $p < 0.05$ level. **Significantly different from CG value at the $p < 0.01$ level. #Significantly different from other EG $p < 0.05$ level;. ##Significantly different from other EG value at the $p < 0.01$ level.

dependent vascular function and structure and sympathetic nervous system regulation, which are altered and may contribute to blood pressure elevation[7,30,31]. Endothelial dysfunction is a determinant factor in vascular function, and it is largely dependent on the bioavailability of nitric oxide (NO), which induces vessel relaxation and regulates blood pressure[32,33]. Strength training may act as a regulator of NO bioavailability by increasing vascular AMPK/PPARδ and suppressing endoplasmic reticulum stress, thereby improving and maintaining endothelial function[34,35]. These results may be in line with previous studies that showed how strength training significantly improved the endothelial function in different population groups[36,37]. In addition, this training modality may also improve vascular structure by increasing artery diameter and reducing vascular intima-media wall thickness[38]. On the other hand, in patients with hypertension, it is common to find an overactivation of the sympathetic nervous system and a reduction in parasympathetic control[30,39]. This physiological imbalance can also be normalised and regularised by strength training as previous research has shown[40,41].

In terms of body composition variables, lean mass, body fat, and waist circumference, both groups showed significant improvements as compared to the CG. Physical exercise induces changes in body composition through skeletal muscles, which are able to release hundreds of myokines into the bloodstream during muscle contraction that are able to interact with the muscle itself and with the rest of the body's organs, resulting in great health benefits[42,43]. These benefits include fat loss and increased muscle mass. The secretion of some of these

Outcome	Group	Pre-test (M ± ED)	Post-test (M ± ED)	Difference post-pre (M ± ED)	p	95% CI (Mpost-Mpre)	Group*time interaction		
							F	Sig	ES
CT (mg/dl)	EG1	199.72 ± 30.11	192.08 ± 29.21	− 7.64 ± 5.52	0.17	− 18.636; 3.356	6.08	<0.001	0.15
	EG2	190.12 ± 41.09	183.12 ± 24.57	− 7.00 ± 5.52	0.209	− 17.996; 3.996			
	CG	191.76 ± 28.51	208.00 ± 29.89	16.24 ± 5.52	0.004	5.244; 27.236			
HDL (mg/dl)	EG1	54.44 ± 9.93	55.32 ± 11.29	0.88 ± 1.07	0.413	− 1.25; 3.01	0.85	0.43	0.02
	EG2	48.04 ± 7.06	49.72 ± 10.25	1.68 ± 1.07	0.12	− 0.45; 3.81			
	CG	48.76 ± 11.10	48.48 ± 12.49	− 0.28 ± 1.07	0.794	− 2.41; 1.85			
LDL (mg/dl)	EG1	120.62 ± 24.78	114.14 ± 24.55	− 6.47 ± 5.01	0.201	− 16.461; 3.517	6.34	<0.001	0.15
	EG2	116.32 ± 36.92	108.22 ± 23.88	− 8.10 ± 5.01	0.111	− 18.085; 1.893			
	CG	116.82 ± 23.25	131.34 ± 31.29	14.52 ± 5.01	0.005	4.531; 24.505			
TG (mg/dl)	EG1	122.32 ± 59.16	113.72 ± 43.21	− 8.60 ± 8.08	0.291	− 24.726; 7.526	2.134	0.126	0.06
	EG2	126.16 ± 51.06	124.88 ± 39.08	− 1.280 ± 8.089	0.875	− 17.406; 14.846			
	CG	133.44 ± 64.33	147.96 ± 79.97	14.520 ± 8.089	0.077	− 1.606; 30.646			
Glucose (mg/dl)	EG1	98.16 ± 14.69	91.36 ± 10.77	− 6.800 ± 1.366**	<0.001	− 9.524; − 4.076	15.99	<0.001	0.31
	EG2	106.84 ± 13.44	99.84 ± 13.77	− 7.000 ± 1.366**	<0.001	− 9.724; − 4.276			
	CG	97.24 ± 22.48	99.80 ± 19.94	2.560 ± 1.366	0.65	− 0.164; 5.284			
Handgrip RA (Kg)	EG1	32.36 ± 10.20	34.52 ± 11.45	2.16 ± 0.59**	<0.001	0.983; 3.337	4.50	0.01	0.11
	EG2	34.40 ± 8.36	36.80 ± 10.30	2.40 ± 0.59**	<0.001	1.223; 3.577			
	CG	32.64 ± 9.63	32.76 ± 9.76	0.12 ± 0.59	0.84	− 1.057; 1.297			
Handgrip LA (Kg)	EG1	30.00 ± 9.61	31.96 ± 11.10	1.96 ± 0.59**	0.001	0.787; 3.133	6.43	<0.001	0.15
	EG2	32.44 ± 8.06	35.56 ± 11.04	3.12 ± 0.59**	<0.001	1.947; 4.293			
	CG	30.20 ± 8.18	30.36 ± 8.22	0.16 ± 0.59	0.786	− 1.013; 1.333			
1RM (UB)	EG1	46.24 ± 23.68	65.12 ± 30.34	− 23.12 ± 2.31**##	<0.001	− 27.715; − 18.525	0.81	0.45	0.02
	EG2	52.08 ± 21.08	61.16 ± 25.30	− 26.04 ± 2.31**	<0.001	− 30.635; − 21.445			
	CG	54.24 ± 24.27	52.20 ± 23.20	− 27.12 ± 2.31	<0.001	− 31.715; − 22.525			
Upper limb MPV (m/s 50%)	EG1	0.96 ± 0.03	1.20 ± 0.06	0.237 ± 0.013**##	<0.001	0.211; 0.263	119.48	<0.001	0.77
	EG2	0.97 ± 0.02	1.08 ± 0.07	0.112 ± 0.013**	<0.001	0.086; 0.139			
	CG	0.97 ± 0.02	0.92 ± 0.04	− 0.050**±0.013	<0.001	− 0.077; − 0.024			
1RM (LB)	EG1	73.08 ± 35.12	98.32 ± 41.42	− 29.23 ± 2.82**#	<0.001	− 34.856; − 23.608	0.26	0.77	0.01
	EG2	74.48 ± 38.23	91.80 ± 42.49	− 29.79 ± 2.82**	<0.001	− 35.416; − 24.168			
	CG	79.92 ± 32.18	76.44 ± 30.73	− 31.97 ± 2.82	<0.001	− 37.592; − 26.344			
Lower limb MPV (m/s 60%)	EG1	0.99 ± 0.02	1.21 ± 0.05	0.225 ± 0.014**#	<0.001	0.197; 0.253	98.01	<0.001	0.73
	EG2	0.99 ± 0.02	1.15 ± 0.07	0.161 ± 0.014**	<0.001	0.133; 0.189			
	CG	0.99 ± 0.02	0.95 ± 0.05	− 0.039 ± 0.014	0.006	− 0.067; − 0.011			
VO2p (ml/kg/min)	EG1	25.09 ± 3.82	30.87 ± 4.41	5.78 ± 0.34**#	<0.001	5.108; 6.452	87.68	<0.001	0.71
	EG2	22.18 ± 4.33	26.78 ± 5.29	4.60 ± 0.34**	<0.001	3.929; 5.274			
	CG	21.62 ± 3.58	21.44 ± 3.58	− 0.18 ± 0.34	0.586	− 0.857; 0.488			
WATT	EG1	127 ± 30.55	167 ± 34.40	40 ± 2.36**	<0.001	35.29; 44.71	98.33	<0.001	0.73
	EG2	125 ± 35.36	162 ± 40.26	37 ± 2.36**	<0.001	32.29; 41.71			
	CG	117 ± 32.05	115 ± 29.76	− 2 ± 2,36	0.4	− 6.71; 2.71			

Table 3. Effect of combined training and endurance training on metabolic biomarkers, and physical fitness. CT: Total Cholesterol; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; TG: Triglycerides; RA: right arm; LA: left arm; 1RM: Maximum Repetition; UL: Upper Limb; LL: Lower Limb; MPV: mean propulsive velocity; VO2p: Peak oxygen consumption. *Significantly different from CG value at the $p < 0.05$ level. **Significantly different from CG value at the $p < 0.01$ level. #Significantly different from other EG $p < 0.05$ level. ##Significantly different from other EG value at the $p < 0.01$ level.

myokines promotes lipolysis and fatty acid oxidation, and induces the darkening of white adipose tissue[43,44]. It is important to note that the participants who performed the concurrent training obtained greater reductions in abdominal perimeter than the participants who performed the endurance training. These results may be due to the fact that strength training favours visceral fat loss by promoting metabolic adaptations in the abdominal subcutaneous adipose tissue, with a significant increase in lipolysis in this area both during and after the training[45,46].

Glucose values in both experimental groups were significantly reduced after the intervention versus the CG. This improvement could be due to the fact that exercise is able to improve insulin sensitivity starting from the first training session, as well as overall glucose homeostasis[47]. Exercise can increase glucose-6-phosphate levels

accompanying the increase in GLUT4, hexokinase, and glycogen synthase activity, leading to an increase in glucose tolerance and a decrease in blood glucose levels[34,47,48].

With respect to the physical condition variables, the participants in both experimental groups showed improvements in both their strength and cardiorespiratory capacity. With regard to strength gains, these were due to the fact that training, regardless of the modality, is able to provoke structural (peripheral) and neural (central) physiological adaptations, given that in all the exercises, muscle action is required to overcome resistance[21,22]. It is important to note that the concurrent training group obtained greater improvements in all the tests than the endurance training group. These results may be due to the specificity of the strength training, which provoked greater adaptations of the central nervous system thanks to a greater recruitment of motor units, their better synchronisation, and the frequency of the stimulus, as already shown in much of the literature[49–52].

Finally, the cardiorespiratory capacity also improved significantly after completion of the exercise programmes in both groups. Exercise promotes adaptations in skeletal muscle such as increased mitochondrial biogenesis and capillary density, thereby improving the ability to transport and use oxygen to generate energy[53–55]. Numerous studies have attributed a key role to peroxisome proliferator-activated receptor gamma coactivator 1α (PGC-1α) in these cardiovascular exercise-induced muscle adaptations[53,55–57]. Although there is a controversy in the literature that concurrent training may interfere with the adaptations induced by the different metabolic pathways, AMPK was activated by endurance training and m-TOR was activated by strength training. However, in this present study, it can be observed that the participants who performed the combined training showed greater improvements in VO_2peak than the participants who performed the endurance training. These results of concurrent training could be justified by the large adaptive reserve of sedentary subjects to any training programme. Previous work has shown that when a previously sedentary subject begins a concurrent training programme, the response to the two exercise modalities is positive and additive, promoting a generic adaptation in the absence of a true specificity of the training effect[58]. Another important factor to consider is the low degree of effort involved in strength training, which would explain why the possible interference would also be low, resulting in greater responses with respect to the maintenance of MHC IIX fibres[59], which could be translated into an improved ability to transport and use oxygen, an increased ability to apply force and a significant improvement in physical fitness.

This study has some limitations that should be taken into account for future research, such as the total intervention time, possibly with longer periods of time more significant results could have been obtained in some of the variables. Another point to consider is the lack of a strength group in which the intensity and volume were not quantified through the speed of execution, but in the traditional way, through the percentage of 1RM and a determined number of repetitions. This would have allowed us to know the effects of the different training programs on blood pressure levels and to continue advancing in the improvement of cardiovascular health. Finally, another limitation was the daily intake of the participants, the diet could have been controlled by making a daily dietary record. Despite the limitations, this would be the first study conducted in an adult population with hypertension, in which the intensity and volume of strength training had been programmed through the velocity of execution, which allowed individualising the work stimulus for each participant with the greatest possible precision, something unknown to date in this population group. In addition, this quantification of the training load allowed the degree of fatigue reached by the participants to be similar throughout the intervention period. This study will provide new insights into the scientific community's multicomponent impact on adults with hypertension. This is the first study to apply a strength-speed training protocol based on training in this population. It also compares it with aerobic training. Controlling this variable is vital for injury prevention[28,29], and the present study shows improvements in hemodynamic parameters, demonstrating reduced fatigue. This improves training control, enhances safety, and reduces the risk of injury.

The findings of the present study indicate that following a strength training programme, based on an individual load-velocity ratio assessment, combined with endurance training at a frequency of 2 days per week for 12 weeks, produces improvements in metabolic and blood biomarkers, body composition, and physical fitness of adults with hypertension, with these adaptations being superior to those produced by endurance training alone, even though the latter showed improvements, but to a lesser extent.

Methods

Study design

A randomised control trial was conducted. A simple randomization method with the software Microsoft Excel (version 2016) was used to distribute subjects into the Experimental Group 1 (EG1) ($n=25$), Experimental Group 2 (EG2) ($n=25$), and Control Group (CG) ($n=25$). Based on blood pressure, a randomised sequence was generated. The group assignment was blinded to the examiner and staff who performed the statistical analysis. The trial design was recorded (22/06/2023) in ClinicalTrial.gov (Code: NCT05914870) and followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines and the Template for Intervention Description and Replication (TIDIER) checklist.

This randomized control trial obtained the approval by the Research Ethics Committee of the Universidad Católica de Murcia (CE062107), in accordance with the Declaration of Helsinki. The Informed Consent document was signed by all participants prior to the start of the study.

Participants

The study included 75 volunteers, 36 women and 39 men (54.45 ± 6.72 years). Figure 1 shows a flowchart representing the Consolidated Standards of Reporting Trials.

The inclusion criteria were: (a) adults with diagnosed hypertension and with follow-up by their primary care physician; (b) being within the age range of 40–65 years old and (c) not having exercised during the last year. The exclusion criteria were: (a) subjects with osteoarticular or musculoskeletal problems that could interfere with

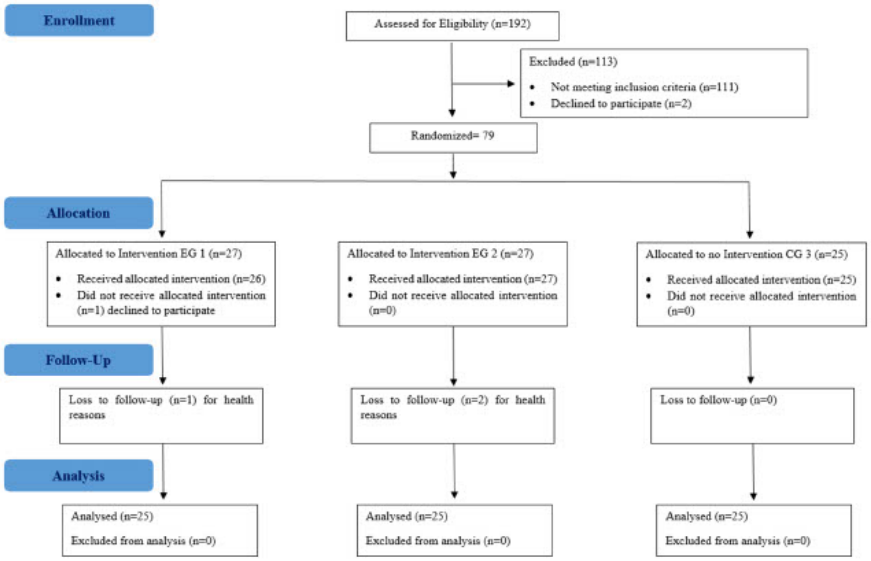


Fig. 1. Consolidated standards of reporting trials flow diagram.

the performance of daily activities; (b) acute or chronic disease that could compromise the subject's autonomy and functional independence; or (c) neurological problems. The participants were instructed not to modify their lifestyle: eating habits and physical activity. The sample size and power calculations were performed using Rstudio 3.15.0 software. The significance level was set at $\alpha = 0.05$ and the power to 95% ($1\text{-}\beta = 0.95$). The standard deviation was used according to the standard deviation for blood pressure from previous studies[60]. A total of 10 mmHg in SBP and 5 mmHg in DBP were set as a minimum clinically significant change[61]. Considering a dropout rate of up to 9.57%[62], 27 participants in each group needed to be enrolled. The final sample provided a power of 95% if found between and within a variance of 4.9 mmHg of SBP and 3.39 mmHg in DBP.

Assessment

Two researches conducted all pre-post intervention measurements under the same conditions. Two weeks before the initial evaluations, all participants were informed of the prerequisites for each of the tests.

Two assessment sessions were necessary, 48–72 h apart from one another. The assessments were carried out in a laboratory with a standardised temperature of 24 °C. The measurements were taken in the morning, between 8:00 and 13:00 h from Monday to Saturday. Height was measured with a SECA 217 stadiometer (SECA, Germany). The Body Composition Analysis was performed with the Body Composition Analyser InBody 770 through the measurement method DSM-BIA (Bioelectric Impedance Multifrequency and Direct Segmental)[63,64]. Prior to the assessment, the participant was informed that they should come to the appointment fasting or at least 3 h after the last meal; 30 min before the assessment, they should not have ingested any liquids; they should not have been to the toilet; they should not have drunk alcohol 48 h before; and they should not wear any metal elements in contact with the skin (rings, bracelets or watches). For the measurement the participant completely cleaned his hands and feet completely with the InBody tissue and stood in front of the equipment; they climbed onto the InBody stepping barefoot on the foot plates and holding the hand electrodes, with arms outstretched without touching the sides of the body and without being allowed to speak or move until the end of the test.

Waist circumference was measured according to the ISAK protocol[65] with a non-elastic tape measure (SECA 200; SECA). The participant stood with their feet together, arms crossed over the chest and relaxed abdomen; the measurement was taken at the narrowest point of the waist at the end of a normal exhalation.

Haemodynamic parameters were assessed using the BPBIO-750 sphygmomanometer, clinically validated according to the ESH protocol[66]. The measurement was performed on the left arm, supported and relaxed on the blood pressure monitor, with the cuff at the level of the heart. Three measurements were taken within 3 min of each other. The mean values of the measurements were taken as a reference[67].

Blood samples were taken by puncturing the cubital vein. The samples were stored in sterile blood tubes in refrigerated conditions (4–8° degrees Celsius (C)) for no longer than 4 h and then sent to testing according

to standardized procedures. Blood glucose was measured using an ultraviolet assay with hexokinase; total cholesterol (TC), high density lipoprotein (HD), and low-density lipoprotein (LDL) were measured using a homogeneous enzymatic colorimetric test, and triglycerides (TG) were measured using enzymatic assay (Cobas 8000 C702, Roche, Mannheim, Germany).

The manual grip force was measured with the Baseline manual hydraulic dynamometer. For the measurement, the participants had to remain seated on the chair with their back against it, feet on the floor, right elbow flexed at 90°, and the wrist in a neutral position. Then, they had to grip the dynamometer with their thumb upwards; once in the correct position, the subject squeezed the grip as tightly as possible for 3 s. The highest peak strength (kilograms (kg)) recorded between the two attempts was considered for analysis[68].

The assessment of lower and upper body strength was carried out through the velocity of execution in the concentric action by means of the Velowin optoelectronic encoder (Velowin v.1.7.232, Instruments and Sports Technology; Murcia, Spain)[24,25]. In addition, the velocity of execution allowed for high precision programming of training intensity and volume. Two tests per body region were carried out, one of progressive loads, to estime 1RM and determine the training load, and the other of loss of velocity in the set (VL%), to establish the number of repetitions, on a Multipower BH TR machine, and the exercises performed were the squat and the bench press[24,25,69]. For reasons of standardization and safety, the concentric phase of each exercise was performed at the maximum possible velocity and the eccentric phase at a slow and controlled velocity, between 3 and 4 s in duration. The squat and bench press tests were performed in different sessions and their order was randomised. All participants performed 2–3 pre-test repetitions in the same evaluation session, they were instructed to move the barbell at the maximum possible speed in the concentric phase and in a slow and controlled manner in the eccentric phase.

For the progressive load test with the squat exercise, the participant stood with knees and hips extended, legs approximately shoulder-width apart and the Multipower bar resting on the upper back. The subject performed the parallel squat downwards in a continuous motion until reaching 80–90° of knee flexion, touching the reference bench, and immediately climbed back up to the starting position at the maximum possible velocity keeping the feet in contact with the ground (without jumping), although the heels could be lifted slightly[70,71]. The initial external load for the squat exercise was set at 15 kg for women and progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs. For men, it was set at 25 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs. Both, males and females executed the exercise until reaching a mean propulsive velocity (MPV) between 0.76 –0.68 $m \cdot s^{-1}$, which corresponds to 75%-80% 1 repetition maximum (1RM) in this exercise. In the test, 5 sets were performed, in the first set the participant performed 3 reps with a very light load which allowed them to move the bar at a lower velocity of 1.28 $m \cdot s^{-1}$ (less than 40% 1RM); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.28 and 1.21 $m \cdot s^{-1}$ (40%-45% 1RM); In the third set, he performed 3 reps with a medium load that allowed him to move the barbell between 1.14 and 1.00 $m \cdot s^{-1}$ (50%-60% 1RM); In the fourth set, they performed 2 reps with a medium-high load that allowed them to move the barbell between 0.92 –0.84 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set he performed 1 rep with a high load that allowed them to shift the bar between 0.76 and 0.68 $m \cdot s^{-1}$ (75%-80% 1RM). The velocity loss (VL) test was performed 24 h after the progressive load test. For this test, a medium workload was defined, the participant was allowed to move the barbell to 0.99 ± 0.02 $m \cdot s^{-1}$, assuming 60% of 1RM, and a low VL magnitude of 10% was set for the squat exercise. The test ended when the subject reached the prescribed VL% limit, regardless of the number of repetitions performed in the set[70,72,73]. For the progressive load test with the bench press exercise, the participant was positioned lying on a horizontal bench with feet resting on the back bar of the Multipower to avoid lumbar arching; hands were placed on the non-slip area of the bar 5–7 cm wider than shoulder width apart. The position of the bench was adjusted so that the bar was aligned with the chest line of each participant. During execution, the eccentric phase of each repetition was performed with controlled speed until the bar was 1–2 cm above the chest, they stopped for 1s, to minimise the contribution of the stretch-shortening cycle, and then pushed the bar at maximum velocity. The initial external load for bench press exercise was set at 10 kg for women and progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs. For men, it was set at 20 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs. Both, males and females executed the exercise until reaching an MPV between 0.55 and 0.47 $m \cdot s^{-1}$, which corresponds to 75%-80% 1RM in this exercise. For the test, 5 sets were performed, in the first set the participant performed 3 reps with a very light load which allowed them to move the bar at a lower speed of 1.13 $m \cdot s^{-1}$ (less than 40% 1RM); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.13 and 1.04 $m \cdot s^{-1}$ (40%-45% 1RM); In the third set, they performed 3 reps with a medium load that allowed him to move the barbell between 0.95 –0.87 $m \cdot s^{-1}$ (50%-60% 1RM); In the fourth set, they performed 2 reps with a medium-high load that allowed them to move the barbell between 0.70 –0.62 $m \cdot s^{-1}$ (65%-70% 1RM); and in the fifth set they performed 1 rep with a high load that allowed him to shift the bar between 0.55 and 0.47 $m \cdot s^{-1}$ (75%-80% 1RM). The velocity loss test was performed 24 h after the progressive load test. For this test, a medium workload was defined, which allowed the participant to move the barbell to 0.97 ± 0.03 $m \cdot s^{-1}$, assuming 50% 1RM, and a low velocity loss magnitude of 15% was set. The test ended when the subject reached the prescribed VL% limit, regardless of the number of repetitions performed in the set[24,72,74].

Cardiorespiratory capacity was assessed using a maximal effort test on the IC7 high-precision cycloergometer with a direct WattRate power meter and an exact magnetic resistance of 300 degrees. The steps lasted 2 min and the pedalling cadence was 70-80ppm. In the first 2 min, the subject pedalled at 50w, after which the load was increased by 25w every 2 min; the test ended when the participants voluntarily decided to stop due to fatigue that prevented them from continuing with the test[75]. The test lasted between 10 and 15 min. The maximum working power was determined as the last 2 min step that the subject was able to complete without interruption, and the ACSM formula was used for the estimation of VO_2max[76]. The following formula was used: VO_2max = (1.8 * workload (kg.m.min-1))/body weight (kg) + 3.5 + 3.5 (where one watt = 6.12 kg.m.min-1). For intensity control

Set	Load	Repetitions	1RM	Squat exercise speed	Bench press speed
1	Very light	3	<40%	< 1.28 m·s^{-1}	< 1.13 m·s^{-1}
2	Light	3	40%-45%	1.28–1.21 m·s^{-}	1.13–1.04 m·s^{-1}
3	Medium	3	50%-60%	1.14–1.00 m·s^{-1}	0.95 –0.87 m·s^{-1}
4	Medium-high	2	65%-70%	0.92 –0.84 m·s^{-1}	0.70 –0.62 m·s^{-1}
5	High	1	75%-80%	0.76–0.68 m·s^{-1}	0.55–0.47 m·s^{-1}

Table 4. Description of the 5-set protocol.

the heart rate (HR) was monitored at all times using the MyZone MZ-3 Heart Rate Monitor[77]. To address the potential limitations of this method of HR monitoring, we simultaneously recorded the subjective perception of exertion (RPE)[78,79] every 10 min during the session, and monitored and recorded the training in watts at all times with the WattRate direct measurement potentiometer[80] via a computer installed in the cycloergometer, helping participants to achieve the prescribed work intensity for each training protocol. In addition, blood pressure and oxygen saturation were monitored during the stress test.

Procedure

The intervention period lasted 12 weeks, 2 days/week, with the sessions lasting 60 min each.

EG1 performed strength training, based on an individual load-velocity ratio assessment, combined with endurance training. The first phase was a warmup of 5 min of Nordic walking on an elliptical bike, joint mobility exercises, and dynamic stretching; and 2 sets of squat and bench press with a light weight. The main phase consisted of 20 min of strength work with a selection of 2 exercises: squat (60% 1RM) and bench press (50% 1RM). For both exercises, 3 sets were performed, with a 3 min rest between sets and the number of repetitions individualised for each participant by the initial speed loss test; the average number of repetitions performed for the squat exercise was 8 repetitions and for the bench press exercise 7 repetitions (Table 4).

The initial absolute loads corresponding to 50% of 1RM in bench press and 60% of 1RM in squat were not modified throughout the intervention period, nor were the number of repetitions set for each participant. Regarding the selection of volume for each of the exercises used, and following a minimum stimulus criterion, we considered the scientific literature regarding the control of this variable by means of the loss of velocity in the sets (VL%), as a more precise way of establishing the degree of effort[24,72,81]. In this way, it was determined that the same loss of velocity in the sets allows for a similar degree of effort or fatigue to be reached between subjects who performed a training protocol with the same relative intensity, although they performed different numbers of repetitions[69,74]. The analysis of the studies already carried out allowed establishing a VL of 25–30% in squat and 35–40% in bench press, as moderate-high degrees of effort beyond which the degree of fatigue begins to have important repercussions at a metabolic and mechanical level, causing a significant reduction in physical capacity and performance[24,69,74]. In strength training, speed losses in the series of less than 20–30% in exercises such as squats or bench presses are associated with better physical fitness results. A speed loss in the set between 10 and 20% is sufficient to achieve significant physical condotion benefits, while losses greater than 30% are closer to muscle failure, which may not be optimal for a health improvement goal. To guarantee the use of a low training volume, for the intensity rates proposed in the present study, VL% was set at 10% for the squat exercise and 15% for the bench press in order to ensure improvements in physical condition and reduce potencial risks, given that the study population is sedentary.

In the last 20 min of the main phase, the participants performed continuous endurance training on a cycloergometer. The training intensity was programmed using the Heart Rate Reserve (HRR) using Karvonen's formula (HRR = HRmax - HRrest); once the HRR was known, the prescribed intensity percentage was calculated (% HR= (HRR × % intensity) + HRrest)[82]. As this was a sedentary population, and the exercise tolerance of each subject was unknown, a moderate intensity range was prescribed for the entire intervention, between 55% and 70% of their heart rate reserve (HRR), in order to achieve the metabolic adaptations already described in the scientific literature[83]. Finally, the post-training phase included 10 min of cool down and static stretching.

As this was a sedentary population, and the exercise tolerance of each subject was unknown, a moderate intensity range was prescribed for the entire intervention, between 55% and 70% of their heart rate reserve (HRR), in order to achieve the metabolic adaptations already described in the scientific literature.

EG2 performed continuous endurance training. The warm-up was the same as EG1 except for the squat and bench press sets. In the main phase, they performed 40 min of continuous endurance training on a cycloergometer, taking into account the same protocol as in EG1. The post-workout phase was the same as EG1.

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 percentage were used for the qualitative variables. A two-way ANOVA analysis of variance with repeated measurements and Bonferroni's correction were used to compare the changes from the baseline between groups, evaluation time interaction, and evaluation time. To protect against a Type I error, Bonferroni's correction was used to achieve a $p = 0.005$ for statistical significance. The effect size was calculated using partial eta-squared ($\eta 2p$) for analysis of variance, and was defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30, large: ES ≥ 1.2; or very large: ES ≥ 2.0; an error of $p \leq 0.05$ is established[84]. All analyses were based on intention-to-treat with an error of $p < 0.05$. The statistical analysis was performed using the statistical package SPSS 24.0 for Windows.

Data availability

Data will be available upon request to the corresponding author.

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References

1. Vaduganathan, M., Mensah, G. A., Turco, J. V., Fuster, V. & Roth, G. A. The global burden of cardiovascular diseases and risk: A compass for future health. *J. Am. Coll. Cardiol.* 80, 2361–2371. https://doi.org/10.1016/j.jacc.2022.11.005 (2022).
2. Liu, X. et al. Dose-Response association between physical activity and incident hypertension: A systematic review and Meta-Analysis of cohort studies. *Hypertension* 69, 813–820. https://doi.org/10.1161/hypertensionaha.116.08994 (2017).
3. Diaz, K. M. & Shimbo, D. Physical activity and the prevention of hypertension. *Curr. Hypertens. Rep.* 15, 659–668. https://doi.org/10.1007/s11906-013-0386-8 (2013).
4. Whelton, P. K. et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: Executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation* 138, e426–e483. https://doi.org/10.1161/cir.0000000000000597 (2018).
5. Pelliccia, A. et al. 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease: The Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). *Eur. Heart J.* 42, 17–96. https://doi.org/10.1093/eurheartj/ehaa605 (2020).
6. Rabi, D. M. et al. Hypertension canada's 2020 comprehensive guidelines for the Prevention, Diagnosis, risk Assessment, and treatment of hypertension in adults and children. *Can. J. Cardiol.* 36, 596–624. https://doi.org/10.1016/j.cjca.2020.02.086 (2020).
7. Mancia, G. et al. 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). *J. Hypertens.* 41, 1874–2071. https://doi.org/10.1097/hjh.0000000000003480 (2023).
8. Hanssen, H. et al. Personalized exercise prescription in the prevention and treatment of arterial hypertension: a consensus document from the European association of preventive cardiology (EAPC) and the ESC Council on hypertension. *Eur. J. Prev. Cardiol.* https://doi.org/10.1093/eurjpc/zwaa141 (2021).
9. López-Ruiz, I., Lozano, F. & Masia, M. D. González-Gálvez, N. Multicomponent training and optimal dosing strategies for adults with hypertension: A systematic review and meta-analysis of randomized controlled trials. *Sports (Basel)* 11. https://doi.org/10.3390/sports11060115 (2023).
10. Bavaresco Gambassi, B. et al. Short-duration dynamic power training with elastic bands combined with endurance training: a promising approach to hypertension management in older adults. *J. Hypertens.* 42, 735–742. https://doi.org/10.1097/hjh.0000000000003681 (2024).
11. Gambassi, B. B. & Schwingel, P. A. Dynamic power training combined with endurance training reduces arterial stiffness and improves hemodynamic parameters in older adults diagnosed with grade 1 hypertension? *J. Hypertens.* 42, 1461–1462 (2024).
12. Masroor, S., Bhati, P., Verma, S., Khan, M. & Hussain, M. E. Heart rate variability following combined aerobic and resistance training in sedentary hypertensive women: A randomised control trial. *Indian Heart J.* 70 (Suppl 3), S28–s35. https://doi.org/10.1016/j.ihj.2018.03.005 (2018).
13. Dos Santos, E. S. et al. Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: a randomized controlled trial. *J. Strength. Cond Res.* 28, 3073–3084. https://doi.org/10.1519/jsc.0000000000000537 (2014).
14. Sousa, N., Mendes, R., Abrantes, C., Sampaio, J. & Oliveira, J. A randomized 9-month study of blood pressure and body fat responses to aerobic training versus combined aerobic and resistance training in older men. *Exp. Gerontol.* 48, 727–733. https://doi.org/10.1016/j.exger.2013.04.008 (2013).
15. Herrod, P. J. J. et al. Exercise and other nonpharmacological strategies to reduce blood pressure in older adults: a systematic review and meta-analysis. *J. Am. Soc. Hypertens.* 12, 248–267. https://doi.org/10.1016/j.jash.2018.01.008 (2018).
16. Pescatello, L. S. et al. Physical activity to prevent and treat hypertension: A systematic review. *Med. Sci. Sports Exerc.* 51, 1314–1323. https://doi.org/10.1249/mss.0000000000001943 (2019).
17. Costa Chaves, L. F. et al. Power exercises with elastic bands combined with endurance training improve pulse pressure, systolic blood pressure, and functional parameters in older adults. *Blood Press. Monit.* 30, 49–56. https://doi.org/10.1097/mbp.0000000000000733 (2025).
18. Hejazi, K. et al. Differential effects of exercise training protocols on blood pressures and lipid profiles in older adults patients with hypertension: A systematic review and meta-analysis. *Arch. Gerontol. Geriatr.* 131, 105737. https://doi.org/10.1016/j.archger.2024.105737 (2025).
19. Amare, F., Kiflu, A. & Taddese, A. Effects of concurrent continuous aerobic and short rest resistance exercise training on metabolic biomarkers in type 2 diabetes patients: a systematic review and meta-analysis. *Diabetol. Metab. Syndr.* 17, 290. https://doi.org/10.1186/s13098-025-01838-x (2025).
20. Poli, L. et al. The effects of multicomponent training on Clinical, Functional, and psychological outcomes in cardiovascular disease: A narrative review. *Medicina (Kaunas)* 61. https://doi.org/10.3390/medicina61050822 (2025).
21. González-Badillo, J. J., Sánchez-Medina, L., Ribas-Serna, J. & Rodríguez-Rosell, D. Toward a new paradigm in resistance training by means of velocity monitoring: A critical and challenging narrative. *Sports Med. Open.* 8, 118. https://doi.org/10.1186/s40798-022-00513-z (2022).
22. Badillo, J. J. G. & Serna, J. R. *Bases De La programación Del Entrenamiento De Fuerza*, Vol. 308 (Inde, 2002).
23. González-Badillo, J. J. Sánchez-Medina, L. Movement velocity as a measure of loading intensity in resistance training. *Int. J. Sports Med.* 31, 347–352. https://doi.org/10.1055/s-0030-1248333 (2010).
24. SÁNCHEZ-MEDINA, L. & GONZÁLEZ-BADILLO, J. J. Velocity loss as an indicator of neuromuscular fatigue during resistance training. *Med. Sci. Sports Exerc.* 43, 1725–1734. https://doi.org/10.1249/MSS.0b013e318213f880 (2011).
25. Conceição, F., Fernandes, J., Lewis, M. & Gonzaléz-Badillo, J. J. Jimenéz-Reyes, P. Movement velocity as a measure of exercise intensity in three lower limb exercises. *J. Sports Sci.* 34, 1099–1106. https://doi.org/10.1080/02640414.2015.1090010 (2016).
26. Díez-Fernández, D. M. et al. Estimating the one-repetition maximum on the leg-press exercise in female breast cancer survivors. *PeerJ* 11, e16175. https://doi.org/10.7717/peerj.16175 (2023).
27. Andreu-Caravaca, L., Ramos-Campo, D. J., Abellán-Aynés, O. & Rubio-Arias, J. Movement velocity as A measure of exercise intensity in persons with multiple sclerosis: A validity study. *J. Clin. Med.* 9. https://doi.org/10.3390/jcm9082458 (2020).
28. McClean, Z. J. et al. A biopsychosocial model for Understanding training Load, Fatigue, and musculoskeletal sport injury in university athletes: A scoping review. *J. Strength. Cond Res.* 38, 1177–1188. https://doi.org/10.1519/jsc.0000000000004789 (2024).
29. Motlagh, J. G. & Lipps, D. B. The contribution of muscular fatigue and shoulder biomechanics to shoulder injury incidence during the bench press exercise: A narrative review. *J. Strength. Cond Res.* 38, 2147–2163. https://doi.org/10.1519/jsc.0000000000004973 (2024).
30. Mancia, G. & Grassi, G. The autonomic nervous system and hypertension. *Circul. Res.* 114, 1804–1814 (2014).

31. Gallo, G., Volpe, M. & Savoia, C. Endothelial dysfunction in hypertension: current concepts and clinical implications. *Front. Med. (Lausanne).* 8, 798958. https://doi.org/10.3389/fmed.2021.798958 (2021).
32. Gamboa, A. et al. Contribution of endothelial nitric oxide to blood pressure in humans. *Hypertension* 49, 170–177. https://doi.org/10.1161/01.hyp.0000252425.06216.26 (2007).
33. Node, K., Kitakaze, M., Yoshikawa, H., Kosaka, H. & Hori, M. Reduced plasma concentrations of nitrogen oxide in individuals with essential hypertension. *Hypertension* 30, 405–408. https://doi.org/10.1161/01.hyp.30.3.405 (1997).
34. Tian, D. & Meng, J. Exercise for prevention and relief of cardiovascular disease: Prognoses, Mechanisms, and approaches. *Oxid. Med. Cell. Longev.* 2019, 3756750. https://doi.org/10.1155/2019/3756750 (2019).
35. Cheang, W. S. et al. PPARδ is required for exercise to attenuate Endoplasmic reticulum stress and endothelial dysfunction in diabetic mice. *Diabetes* 66, 519–528. https://doi.org/10.2337/db15-1657 (2017).
36. Ashor, A. W. et al. Exercise modalities and endothelial function: a systematic review and dose-response meta-analysis of randomized controlled trials. *Sports Med.* 45, 279–296. https://doi.org/10.1007/s40279-014-0272-9 (2015).
37. Zhang, Y., Zhang, Y. J., Zhang, H. W., Ye, W. B. & Korivi, M. Low-to-Moderate-Intensity resistance exercise is more effective than High-Intensity at improving endothelial function in adults: A systematic review and Meta-Analysis. *Int. J. Environ. Res. Public. Health* 18. https://doi.org/10.3390/ijerph18136723 (2021).
38. Spence, A. L., Carter, H. H., Naylor, L. H. & Green, D. J. A prospective randomized longitudinal study involving 6 months of endurance or resistance exercise. Conduit artery adaptation in humans. *J. Physiol.* 591, 1265–1275. https://doi.org/10.1113/jphysiol.2012.247387 (2013).
39. Fisher, J. P. & Paton, J. F. The sympathetic nervous system and blood pressure in humans: implications for hypertension. *J. Hum. Hypertens.* 26, 463–475. https://doi.org/10.1038/jhh.2011.66 (2012).
40. Laterza, M. C. et al. Exercise training restores baroreflex sensitivity in never-treated hypertensive patients. *Hypertension* 49, 1298–1306. https://doi.org/10.1161/hypertensionaha.106.085548 (2007).
41. Trevizani, G. A. et al. Effect of resistance training on blood pressure and autonomic responses in treated hypertensives. *J. Strength. Cond Res.* 32, 1462–1470. https://doi.org/10.1519/jsc.0000000000001995 (2018).
42. Pedersen, B. K. & Saltin, B. Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scand. J. Med. Sci. Sports.* 25 (Suppl 3), 1–72. https://doi.org/10.1111/sms.12581 (2015).
43. Pedersen, B. K. The anti-inflammatory effect of exercise: its role in diabetes and cardiovascular disease control. *Essays Biochem.* 42, 105–117. https://doi.org/10.1042/bse0420105 (2006).
44. Brandt, C. & Pedersen, B. K. The role of exercise-induced myokines in muscle homeostasis and the defense against chronic diseases. *J. Biomed. Biotechnol.* 2010, 520258. https://doi.org/10.1155/2010/520258 (2010).
45. Khalafi, M., Malandish, A., Rosenkranz, S. K. & Ravasi, A. A. Effect of resistance training with and without caloric restriction on visceral fat: A systemic review and meta-analysis. *Obes. Rev.* 22, e13275. https://doi.org/10.1111/obr.13275 (2021).
46. Wewege, M. A. et al. *Sports Med.* 52, 287–300 (2021).
47. Mul, J. D., Stanford, K. I., Hirshman, M. F. & Goodyear, L. J. Exercise and regulation of carbohydrate metabolism. *Prog Mol. Biol. Transl Sci.* 135, 17–37. https://doi.org/10.1016/bs.pmbts.2015.07.020 (2015).
48. Way, K. L., Hackett, D. A., Baker, M. K. & Johnson, N. A. The effect of regular exercise on insulin sensitivity in type 2 diabetes mellitus: A systematic review and Meta-Analysis. *Diabetes Metab. J.* 40, 253–271. https://doi.org/10.4093/dmj.2016.40.4.253 (2016).
49. Sale, D. G. Neural adaptation to resistance training. *Med. Sci. Sports Exerc.* 20, 135–145. https://doi.org/10.1249/00005768-198810001-00009 (1988).
50. Enoka, R. M. Neural adaptations with chronic physical activity. *J. Biomech.* 30, 447–455. https://doi.org/10.1016/s0021-9290(96)00170-4 (1997).
51. Del Vecchio, A. et al. The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. *J. Physiol.* 597, 1873–1887. https://doi.org/10.1113/jp277250 (2019).
52. Folland, J. P. & Williams, A. G. Morphological and neurological contributions to increased strength. *Sports Med.* 37, 145–168 (2007).
53. Akimoto, T. et al. Exercise stimulates Pgc-1alpha transcription in skeletal muscle through activation of the p38 MAPK pathway. *J. Biol. Chem.* 280, 19587–19593. https://doi.org/10.1074/jbc.M408862200 (2005).
54. Booth, F. W., Ruegsegger, G. N., Toedebusch, R. G. & Yan, Z. Endurance exercise and the regulation of skeletal muscle metabolism. *Prog Mol. Biol. Transl Sci.* 135, 129–151. https://doi.org/10.1016/bs.pmbts.2015.07.016 (2015).
55. Jung, S. & Kim, K. Exercise-induced PGC-1α transcriptional factors in skeletal muscle. *Integr. Med. Res.* 3, 155–160 (2014).
56. Baar, K. et al. Adaptations of skeletal muscle to exercise: rapid increase in the transcriptional coactivator PGC-1. *Faseb j.* 16, 1879–1886. https://doi.org/10.1096/fj.02-0367com (2002).
57. Halling, J. F. & Pilegaard, H. PGC-1α-mediated regulation of mitochondrial function and physiological implications. *Appl. Physiol. Nutr. Metab.* 45, 927–936. https://doi.org/10.1139/apnm-2020-0005 (2020).
58. Coffey, V. G. & Hawley, J. A. Concurrent exercise training: do opposites distract? *J. Physiol.* 595, 2883–2896. https://doi.org/10.1113/jp272270 (2017).
59. Pareja-Blanco, F. et al. Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations. *Scand. J. Med. Sci. Sports.* 27, 724–735. https://doi.org/10.1111/sms.12678 (2017).
60. Schroeder, E. C., Franke, W. D., Sharp, R. L. & Lee, D. C. Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PLoS One.* 14, e0210292. https://doi.org/10.1371/journal.pone.0210292 (2019).
61. Gorostidi, M. et al. Guía práctica sobre El diagnóstico y Tratamiento de La hipertensión arterial En España, 2022. Sociedad Española de Hipertensión-Liga Española Para La Lucha contra La Hipertensión arterial (SEH-LELHA). *Hipertensión Y Riesgo Vascular.* 39, 174–194 (2022).
62. Stewart, K. J. et al. Effect of exercise on blood pressure in older persons: a randomized controlled trial. *Arch. Intern. Med.* 165, 756–762. https://doi.org/10.1001/archinte.165.7.756 (2005).
63. Buch, A. et al. Validation of a multi-frequency bioelectrical impedance analysis device for the assessment of body composition in older adults with type 2 diabetes. *Nutr. Diabetes.* 12, 45. https://doi.org/10.1038/s41387-022-00223-1 (2022).
64. Lahav, Y., Goldstein, N. & Gepner, Y. Comparison of body composition assessment across body mass index categories by two multifrequency bioelectrical impedance analysis devices and dual-energy X-ray absorptiometry in clinical settings. *Eur. J. Clin. Nutr.* 75, 1275–1282. https://doi.org/10.1038/s41430-020-00839-5 (2021).
65. Marfell Jones, M., Olds, T., Stewart, A. & Carter, L. Sociedad Internacional para el Avance de la Cineantropometría (ISAK). *Manual ISAK* (2006).
66. Hypertension, E. S. o. (2010).
67. Stergiou, G. S. et al. European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement. *J. Hypertens.* 39, 1293–1302. https://doi.org/10.1097/hjh.0000000000002843 (2021).
68. Mathiowetz, V. et al. Grip and pinch strength: normative data for adults. *Arch. Phys. Med. Rehabil.* 66, 69–74 (1985).
69. Rodríguez-Rosell, D., Yáñez-García, J. M., Sánchez-Medina, L., Mora-Custodio, R. & González-Badillo, J. J. Relationship between velocity loss and repetitions in reserve in the bench press and back squat exercises. *J. Strength. Conditioning Res.* 34, 2537–2547 (2020).

70. Sánchez-Medina, L., Pallarés, J. G., Pérez, C. E., Morán-Navarro, R. & González-Badillo, J. J. Estimation of relative load from bar velocity in the full back squat exercise. *Sports Med. Int. open.* 1, E80–E88 (2017).
71. Escamilla, R. F. Knee biomechanics of the dynamic squat exercise. *Med. Sci. Sports Exerc.* 33, 127–141. https://doi.org/10.1097/00005768-200101000-00020 (2001).
72. Rodríguez-Rosell, D. et al. Velocity-based resistance training: impact of velocity loss in the set on neuromuscular performance and hormonal response. *Appl. Physiol. Nutr. Metab.* 45, 817–828. https://doi.org/10.1139/apnm-2019-0829 (2020).
73. Morán-Navarro, R. et al. Movement velocity as a measure of level of effort during resistance exercise. *J. Strength. Cond Res.* 33, 1496–1504. https://doi.org/10.1519/jsc.0000000000002017 (2019).
74. González-Badillo, J. J., Yañez-García, J. M. & Mora-Custodio, R. Rodríguez-Rosell, D. Velocity loss as a variable for monitoring resistance exercise. *Int. J. Sports Med.* 38, 217–225. https://doi.org/10.1055/s-0042-120324 (2017).
75. Marqueta, P. M. et al. Pruebas de esfuerzo en medicina del deporte. Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE). *Arch. Med. Deporte* 33, 5–83 (2016).
76. Ferguson, B. *J. Can. Chiropr. Assoc.* 58, 328 (2014).
77. Cuadros, L., Ismail, H. & Ho, K. Evaluation of reliability of MYZONE MZ-3 heart rate monitor: A study for the future of telephysiotherapy for preoperative prehabilitation in cancer patients. *Telemed J. E Health.* 23, 334–338. https://doi.org/10.1089/tmj.2016.0138 (2017).
78. Borg, G. *Borg's Perceived Exertion and Pain Scales* (Human Kinetics, 1998).
79. Lea, J. W. D., O'Driscoll, J. M., Hulbert, S., Scales, J. & Wiles, J. D. *Sports Med. Open* 82 (2022).
80. Allen, H., Coggan, A. R. & McGregor, S. *Training and Racing with a Power Meter* (VeloPress, 2019).
81. Pareja-Blanco, F., Sánchez-Medina, L., Suárez-Arrones, L. & González-Badillo, J. J. Effects of velocity loss during resistance training on performance in professional soccer players. *Int. J. Sports Physiol. Perform.* 12, 512–519. https://doi.org/10.1123/ijspp.2016-0170 (2017).
82. Karvonen, M. J., Kentala, E. & Mustala, O. The effects of training on heart rate; a longitudinal study. *Ann. Med. Exp. Biol. Fenn.* 35, 307–315 (1957).
83. Mølmen, K. S., Almquist, N. W. & Skattebo, Ø. Effects of exercise training on mitochondrial and capillary growth in human skeletal muscle: A systematic review and Meta-Regression. *Sports Med.* 55, 115–144. https://doi.org/10.1007/s40279-024-02120-2 (2025).
84. Hopkins, W. G., Marshall, S. W., Batterham, A. M. & Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* 41, 3–13. https://doi.org/10.1249/MSS.0b013e31818cb278 (2009).

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Author contributions
I.L.-R. and N.G.-G: conceived and designed the experiments; I.L.-R., F.L.R.-P., M.D.M., J.R.H.-E. and N.G.-G.: performed the experiments; I.L.-R. and N.G.-G: analysed the data, I.L.-R. and N.G.-G: wrote the manuscript; I.L.-R., F.L.R.-P., M.D.M., J.R.H.-E. and N.G.-G.: proofed the manuscript. All authors have proofed the article.

Declarations

Competing interests
The authors declare no competing interests.

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ANEXO 16. Estudio 3. Moderate intensity continuous training, combined moderate-intensity continuous training vs combined high-intensity interval training in adults with hypertension: Randomized controlled trial

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Moderate intensity continuous training, combined moderate-intensity continuous training vs combined high-intensity interval training in adults with hypertension: Randomized controlled trial

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ABSTRACT

Background and purpose: Despite all efforts to treat hypertension, it is still responsible for 10.8 million deaths annually. The aim of this study was to compare the effects of continuous moderate-intensity training, strength training combined with continuous moderate-intensity training and strength training combined with high-intensity interval training in adults with high blood pressure.
Methods: A 12-week randomized control trial was performed. A total of 100 volunteers, 51 women and 49 men with hypertension participated. The sample was randomly assigned into three intervention groups and one control group.
Results: All intervention groups significantly improved their hemodynamic parameters, body composition, lipid profile, glucose, and physical fitness as compared to the control group. Both combined training groups showed greater improvements than the moderate-intensity continuous training group. However, the strength group combined with the moderate-intensity continuous group showed the greatest benefits in systolic, diastolic and mean arterial pressure, of −13.4 mmHg, −6.8 mmHg and −8.9 mmHg respectively, abdominal circumference, upper and lower limb strength and VO_2peak, versus the continuous moderate-intensity group; it also achieved greater reductions in systolic and mean blood pressure, up to −6.8 mmHg and 4.3 mmHg respectively, than the strength group combined with the high intensity interval group.
Conclusion: Performing a strength training program combined with continuous moderate intensity training, 2 days per week for 12 weeks, produces significant improvements in cardiometabolic biomarkers, body composition, and physical condition of adults with hypertension, with these adaptations being superior to those produced by continuous moderate-intensity training and strength training combined with high-intensity intervallic training.

1. Introduction

Hypertension is a chronic, virtually asymptomatic disorder that deteriorates the quality of blood vessels and can lead to target organ damage if not diagnosed early and properly controlled. It remains the most prevalent modifiable risk factor worldwide, and is responsible for more than 10 million deaths per year from cardiovascular disease [1,2]. In this sense, hypertension is considered at 140 mmHg systolic blood pressure (SBP) and 90 mmHg diastolic blood pressure (DBP); although an optimal control is below 130 mmHg and 85 mmHg respectively [3].

An active lifestyle is essential to address this disorder, as exercise acts as a drug that can prevent and treat many non-communicable diseases, including hypertension [4,5]. Moderate-intensity continuous training (MICT) is a priority for this population, according to the main clinical guidelines in cardiology and hypertension, with a minimum of 3 days/week and with a volume of 150–300 min/week at moderate intensity or 75–150 min/week at vigorous intensity [6–8], to achieve reductions in SBP from −4.9 to −12 mmHg and DBP from −3.4 to −5.8 mmHg [8,

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9]. Furthermore, the inclusion of strength training at least 2 days/week is recommended to benefit from the health improvements provided by this modality [10], including reductions in SBP from −3.0 to −4.7 mmHg and DBP from −3.2 to −3.8 mmHg [6,7]; Some of these guidelines also specify a total of 8–10 exercises per session involving large muscle groups and performing 8–12 repetitions per exercise [8]. These exercise guidelines do not include strength training combined with MICT in the same training session. However, different scientific publications have shown significant improvements in SBP and DBP levels with these training modalities [11–15]; Nevertheless, despite the benefits of combined training, further research is needed to establish dose-response relationships [16,17]. Another training modality that has also been shown to improve blood pressure levels is high-intensity interval training (HIIT) [18–21]. Recently, this training modality, because of its time efficiency and the growing evidence available, has been proposed as an alternative to MICT [18–20]. While this modality alone has shown similar improvements in blood pressure levels [19,20,22], even higher in diurnal SBP or vascular function than MICT for the control of hypertension, according to recent meta-analyses [18–22], little research has combined strength work with HIIT in this population group [23,24], even though this tool may provide greater cardiometabolic health benefits.

On the other hand, the programming of training is a complicated task, and even more so when it comes to programming the degree of effort for strength improvement. In the literature that can be found on strength training and hypertension, strength has been assessed by performing 1RM (one-repetition maximum) tests, a method considered the gold standard, but which involves an excessive, inaccurate and even harmful effort [25,26]; and for the volume of work, a fixed number of repetitions has been determined for all participants, resulting in a different degree of effort for each of them, as has been shown in previous work [25–27]. Until recently, it was difficult to truly know the relative intensity at which one was working, and thus the intensity at which a certain effect was produced. This was solved when the speed of execution emerged, a tool that represents a paradigm shift in the field of training by providing accurate information on the programmed load and the effects produced by it [28–30]. Currently, a large number of studies can be found with different population groups, in which the speed of execution has been used for the dosage of the training load; young men [29], multiple sclerosis patients [31], older women [32], or cancer survivors [33]. However, there are no contributions from the measurement of movement velocity in cardiovascular pathology, and more specifically in hypertension. One of the main problems with previous works is the lack of rigor in training programming; intensity and volume were not measured as accurately as possible, and it is therefore not possible to know whether the participants underwent the same amount of training, with the same relative intensity and the same degree of fatigue.

Therefore, the aim of the present study was to compare the effects of different individualized training programs: continuous moderate-intensity training, strength training combined with continuous moderate-intensity training, and strength training combined with high-intensity interval training, in adults with arterial hypertension.

2. Methodology

2.1. Study design

A randomized controlled clinical trial with several simultaneous study branches was conducted; the study was single-blind, longitudinal, and prospective. To distribute subjects into experimental group 1 (EG1), experimental group 2 (EG2), experimental group 3 (EG3), and control group (CG) a simple randomization method with the Microsoft Excel software (version 2016) was used. Four group were established based on blood pressure values, after which a randomized sequence was generated using simple randomization. The group assignment was blinded to the examiner and staff who performed the statistical analysis. This research followed the guidelines from the Consolidated Standards of Reporting Trials (CONSORT) statement, and the Template for Intervention Description and Replication (TIDieR) checklist. The trial design was registered at ClinicalTrial.gov (Code: NCT05914870).

In accordance with de Declaration of Helsinki, this randomized control trial obtained the approval of the Research Ethics Committee of the Universidad Católica de Murcia (CE062107). The Informed Consent

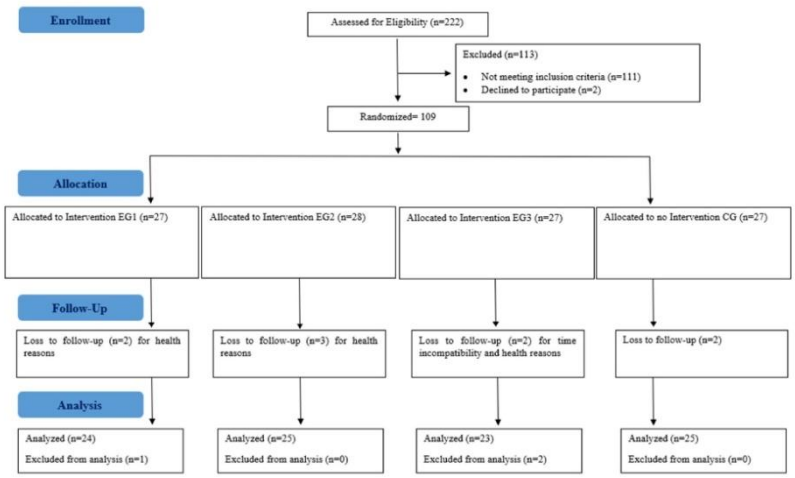


Fig. 1. Flow diagram.

document was signed by all participants prior to the start of the study.

2.2. Participants

A total of 100 volunteers participated, 51 women and 49 men, all of them with hypertension, a mean age 54 years, and previously sedentary. The sample was randomly assigned into three experimental and one control group: EG1, moderate-intensity continuous training or MICT, (n = 24); EG2, strength training combined with MICT, (n = 25); EG3, strength training combined with HIIT, (n = 23); and CG, control group, (n = 25) (see Fig.1).

The inclusion criteria were: a) adults with diagnosed hypertension and with follow-up by their primary care physician; b) age range 40–65 years; (c) not engaged in at least 150 min of moderate physical activity per week or 75 min of vigorous physical activity per week or a combination of both during the past 12 months. The exclusion criteria were: a) subjects with osteoarticular or musculoskeletal problems that conditioned the development of the intervention; b) uncontrolled or training-limiting cardiometabolic diseases such as heart disease, unstable coronary artery disease, heart failure, renal failure, diabetes, or morbid obesity; c) neurological problems; d) cognitive impairment that hinders the understanding and performance of the training; e) subjects who are dependent in the performance of daily activities; or f) pregnant women. Participants were instructed not to change their eating habits. The sample size and power calculations were performed using Rstudio 3.15.0 software. The significance level was set at $\alpha = 0.05$ and the power to 95 % ($1\text{-}\beta = 0.95$). The standard deviation used was according to the standard deviation for blood pressure found in previous studies [34]. A minimum clinically significant change of a total of 10 mmHg in SBP and 5 mmHg in DBP was considered [35]. With a dropout rate of up to 9.57 % [36], the aim was to enroll at least 26 participants in each group. The final sample provided a power of 95 % if found between and within a variance of 4.6 mmHg of DBP and 3.2 mmHg in DBP.

2.3. Assessment tools and protocols

The pre-post intervention measurements were carried out in the morning, between 8:00 and 13:00 h, by two researchers. They were carried out in a laboratory at a temperature of 24 °C, in two different assessment sessions, with a difference of 48–72 h between them and always under the same conditions. The height of the participants was measured with a SECA 217 stadiometer (SECA, Germany). Body Composition was assessed with the InBody 770 analyzer using the DSM-BIA measurement method (Multifrequency and Direct Segmental Bioelectrical Impedance) [37,38]. The analysis was performed on an empty stomach, without drinking liquids 30 min before the test, without drinking alcohol 48 h before the test and without wearing metallic elements in contact with the skin such as chokers, rings, belts, etc. For the assessment, the subject wiped their hands and feet with the InBody tissue, then climbed forwards onto the equipment, placing their feet on the plates, and grasping the electrodes with their hands with arms extended away from the sides of the body, without speaking and without moving until the end of the test.

Abdominal girth was measured with a non-elastic tape measure (SECA 200; SECA) according to the ISAK protocol [39]; standing with feet together, arms crossed on the chest and abdomen relaxed. The measurement was taken at the narrowest part of the waist after a normal exhalation.

The evaluation of the hemodynamic parameters, SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), PP (pulse pressure) and RPP (rate pressure product), was performed with the BPBIO-750 sphygmomanometer [40]. For the test, the participants, after sitting for 5 min before the measurement, placed the left arm relaxed and supported on the blood pressure monitor, with the cuff at the level of the heart, their back supported, legs parallel without crossing and in silence during the test. Three measurements were taken 3 min apart, and the average of the last two measurements was taken as the reference value [41].

Blood chemistry analyses were performed from 8:00 to 9:00 a.m., after a minimum fasting period of 10 h. Samples were stored in sterile tubes under refrigeration (4–8 °C) for a maximum of 4 h, and then analyzed according to standardized procedures. Total cholesterol (TC), high-density lipoproteins (HDL), and low-density lipoproteins (LDL), were measured by a homogeneous enzymatic colorimetric assay, while triglycerides (TG) were measured by an enzymatic assay. (Cobas 8000C702, Roche, Mannheim, Germany); and glucose by an ultraviolet hexokinase assay (Cobas 8000C702, Roche, Mannheim, Germany).

The manual hydraulic dynamometer Baseline was used to assess the manual gripping force. The test was performed with the participant seated on a chair, back supported, feet on the floor, right elbow flexed at 90°, and holding the dynamometer with the wrist in neutral position with the thumb upwards; on command, the subject squeezed the grip as hard as possible for 3 s. The same procedure was repeated with the left hand. Two measurements were made with both hands and the highest maximum force (kg) of the two attempts was considered [42].

For the assessment of the maximum upper and lower body strength and the programming of the training, different tests were carried out using the speed of execution in the concentric motion with the Velowin optoelectronic encoder (Velowin v.1.7.232, Instruments and Sports Technology; Murcia, Spain) [28,29]. Two tests were carried out per body region on the Multipower BH TR machine, one of progressive loads, and the other of velocity loss in the set (%VL); the exercises performed were the squat and the bench press [28–30,43]. The tests were carried out in different sessions, 24 h apart, and before starting the tests, the participant underwent a standardized general warm-up.

For the technical execution of the progressive load test in the squat exercise, the protocol described in previous studies was followed [44,45]. The initial external load for the squat exercise was set at 15 kg for women and was progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs until a mean propulsive velocity (MPV) between 0.76 and 0.68 m s^{-1} was reached, which corresponds to 75%–80 % 1RM in this exercise; for men, the initial weight was set at 25 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs until an MPV between 0.76 and 0.68 m s^{-1} was reached, which corresponds to 75%–80 % 1RM in this exercise. During the test, 5 sets were performed; in the first set, the participants performed 3 reps with a very light load that allowed them to move the bar at a speed <1.28 m s^{-1} (<40 % 1RM); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.28 and 1.21 m s^{-1} (40%–45 % 1RM); in the third set, they performed 3 reps with a medium load that allowed them to move the bar between 1.14 and 1.00 m s^{-1} (50%–60 % 1RM); in the fourth set, they performed 2 reps with a medium-high load that allowed them to move the bar between 0.92 and 0.84 m s^{-1} (65%–70 % 1RM); and in the fifth set, they performed 1 rep with a high load that allowed them to move the bar between 0.76 and 0.68 m s^{-1} (75%–80 % 1RM) [28,31–33,46]. The velocity loss test was performed 24 h after the progressive load test. For this test, a workload was defined that allowed the participant to move the bar at 0.99 ± 0.02 m s^{-1}, assuming 60 % of 1RM, and a velocity loss magnitude of 10 % was established. The test ended when the subject reached the prescribed %VL limit, regardless of the number of repetitions performed in the series [47,48].

For the technical execution of the progressive load test in the bench press exercise, the protocol described in previous studies was followed [31,32]. The initial external load for the bench press exercise was set at 10 kg for the women and was progressively increased individually with 5 kg, 2.5 kg and 1.25 kg discs until a MPV between 0.55 and 0.47 m s^{-1} was reached, which corresponds to 75%–80 % 1RM in this exercise; for men, the initial weight was set at 20 kg and progressively increased individually with 10 kg, 5 kg and 2.5 kg discs until an MPV between 0.55 and 0.47 m s^{-1} was reached, which corresponds to 75%–80 % 1RM in this exercise. For the test, 5 sets were performed; in the first set, the participants performed 3 reps with a very light load that allowed them to

move the bar at a speed <1.13 m s^{-1} (<40 %); in the second set, they performed 3 reps with a light load that allowed them to move the bar between 1.13 and 1.04 m s^{-1} (40%–45 % 1RM); in the third set, they performed 3 reps with a medium load that allowed them to move the bar between 0.95 and 0.87 m s^{-1} (50%–60 % 1RM); in the fourth set, they performed 2 reps with a medium-high load that allowed them to move the bar between 0.70 and 0.62 m s^{-1} (65%–70 % 1RM); and in the fifth set they performed 1 rep with a high load that allowed them to move the bar between 0.55 and 0.47 m s^{-1} (75%–80 % 1RM) [28,31,32]. The velocity loss test was performed 24 h after the progressive load test. A workload was defined that allowed the participant to move the bar at 0.97 ± 0.03 m s^{-1}, assuming 50 % 1RM, and a magnitude of velocity loss of 15 % was established. The test ended when the subject reached the prescribed %VL limit, regardless of the number of repetitions performed in the series [29,43].

Cardiorespiratory fitness was assessed with the IC7 cycloergometer, with a high-precision potentiometer with a direct WattRate measurement and an accurate magnetic resistance of 300°. For the adjustment of the bicycle, the protocol described in previous studies was followed [49]. **The test consisted of a** clinical step test with progressive loads; the steps lasted 2 min and the pedaling cadence was between 70 and 80 bpm. In the first 2 min, the subject pedaled at 50 W, then the load was increased by 25 W every 2 min; the test ended when the participant decided to stop voluntarily due to fatigue [50]. The maximum working power was established as the last 2 min step that the subject was able to complete. The VO_2max was estimated using the formula described by the ACSM [51]: VO_2max = (1.8 *workload (kg.m.min-1))/body weight (kg) + 3.5 + 3.5 (where 1 W = 6.12 kg m.min-1).

2.4. Procedure

The intervention period lasted 12 weeks, the training frequency was 2 days/week (24 sessions) and the length of time per session was 60 min.

EG1 performed a MICT session starting with 10 min of standardized general warm-up, 5 min of Nordic walking on an elliptical trainer, joint mobility exercises, and dynamic stretching. In the main phase, they performed 40 min of continuous aerobic endurance training on a cycloergometer, without breaks, maintaining the same intensity range throughout the session; the intensity was increased every 4 weeks, from weeks 1–4 they worked at 55%–60 % heart rate reserve (HRR), from weeks 5–8 at 60%–65 % HRR, and from weeks 9–12 at 65%–70 % HRR. Finally, a 10 min post-workout phase with a cool down and static stretching took place.

EG2 performed strength training, based on an individual load-velocity ratio assessment, combined with MICT. The session started with 10 min of standardized general warm-up, 5 min of Nordic walking on the elliptical machine, joint mobility exercises, and dynamic stretching. Finally, a more specific warm-up was performed. The participants performed 2 sets of each exercise, squat and bench press, only with the weight of the bar (5 kg); the first set consisted of 8–10 reps and the second set of 6–8 reps; the rest between sets was 2 min. The main training phase was divided into two 20-min blocks. During the first 20 min, they performed 2 strength exercises that reproduced basic motor actions. The first exercise was a lower hemisphere push (squat) with an intensity of 60 % of their 1RM; 3 sets were performed with the number of repetitions individualized for each subject using the initial speed loss test, and the rest between sets and between exercises was 3 min. The second exercise was a bench press at an intensity of 50 % of their 1RM. Regarding the selection of volume, the analysis of previous studies indicated a %VL of 25–30 % in squat and 35–40 % in bench press, as a medium-high effort value above which the degree of fatigue begins to increase, causing a significant decrease in performance [27,29,43]. **Following a minimum stimulus criterion, in order to guarantee a low training volume, and considering the intensities proposed in this study, a 10 % %VL was established for the squat exercise and 15 % for the bench press. In the last 20 min of the main phase, the participants performed continuous moderate-intensity training on a cycloergometer; the intensity of the training increased every 4 weeks. Thus, from weeks 1 to 4, they trained at 55%-60 % HRR, from weeks 5 to 8, at 60%-65 % HRR, and from weeks 9 to 12, at 65%-70 % HRR. Finally, a 10 min post-training phase with cool down and static stretching took place.**

EG3 performed strength training, based on an individual load-velocity ratio assessment, combined with HIIT. This group performed the same warm-up protocol and the first 20 min of the main phase as EG2. In the last 20 min of the main phase, they performed high-intensity interval training on a cycloergometer. Following the review of previous studies, and the lack of a standardized protocol for this training modality in adults with hypertension [19,20], a work-recovery ratio of 1:1, 2 min work: 2 min active recovery was established following previous work in cardiac rehabilitation and cardiovascular pathology [52–54]. In addition, based on the European Society of Cardiology (ESC) classification of aerobic training intensity from maximal ergometry [6], an intensity of 80–85 % HRR was determined for the training time, and 55%–60 % HRR for the active recovery time. The review of the latest ESC documents allowed for the following ranges of intensity: <40 % low intensity HRR, 40–69 % moderate intensity HRR, 70–85 % high intensity HRR, and >85 % very high intensity HRR [6,55]. Training intensities were not modified during the intervention. Finally, a 10 min post-training phase with a return to calm and static stretching took place. The heart rate was monitored using the MyZone MZ-3 Heart Rate Monitor, which allowed the HR to be monitored at all times. In addition, the subjective rate of perceived exertion (RPE) was recorded simultaneously [56], as well as the training in watts, with the WattRate direct measurement potentiometer [57], by means of a computer integrated in the cycloergometer.

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. A two-way analysis of variance (ANOVA) with repeated measurements and Bonferroni's correction will be used to compare the changes from the baseline between groups, the evaluation time interaction, and evaluation time. 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 (η2p) for analysis of variance, and will be defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30, large: ES ≥ 1.2; or very large: ES ≥ 2.0. Lastly, an error of $p \leq 0.05$ was used [58]. All analyses were based on intention-to-treat with an error of $p < 0.05$. The statistical analysis was performed using the statistical package SPSS 24.0 for Windows.

3. Results

Table 1 shows the characteristics of the sample, and Tables 2 and 3 show the pre-post intervention results of EG1, EG2, EG3, and CG. In addition, group * time interaction is also presented.

On the one hand, EG1, EG2, and EG3 showed significant improvements in SBP, DBP, MAP, RHrest, lean mass, waist circumference, TC, LDL, glucose, handgrip strength, 1RM upper body, upper limb MPV (m/s 50 %), 1RM lower body, lower limb MPV (m/s 60 %), and VO_2peak, with these changes being significantly greater than those of the CG. On the other hand, EG2 obtained greater changes in SBP, DBP, MAP, PP, RPP, waist circumference, 1RM upper body, upper limb MPV (m/s 50 %), 1RM lower body, and lower limb MPV (m/s 60 %) than EG1.

EG2 also showed further improvements in SBP, MAP, RPP, 1RM upper limb, upper limb MPV (m/s 50 %), and VO_2peak than EG3.

Finally, the EG3 achieved major improvements in SBP, MAP, and RPP than EG1. Furthermore, it was the only intervention group that significantly reduced BFP (body fat percentage) with respect to the CG.

Table 1
Characteristics of the sample.

Variable		% (n) or M±SD
Sex	Female	51.54 [50]
	Male	48.45 [47]
Age		54.17 ± 6.70
Marital Status	Married	87.00 [59]
	Single	11.00 [11]
	Widow	2.00 [2]
Occupation	Full-Time Worker	49.00 [49]
	Part-Time Worker	4.00 [4]
	Unemployed	16.00 [16]
	Self-Employed	10.00 [10]
	Retired	21.00 [21]
Level of Education	No Education	9.00 [9]
	Elementary School	32.00 [32]
	Secondary School	16.00 [16]
	High School	25.00 [25]
	University Education	18.00 [18]
Living Status	Living with Someone	87.00 [59]
	Living Alone	13.00 [13]

4. Discussion

The aim of the present study was to compare the effects of different individualized training programs, i.e., MICT, strength training combined with MITC, and strength training combined with HIIT, in adults with high blood pressure. The results showed that EG1, EG2, and EG3 significantly improved blood pressure levels, while the CG showed no change. One of the main findings of this research was that both groups with combined training showed greater improvements in these variables, with strength training combined with MICT showing the greatest benefits. It can be observed that the reductions in blood pressure levels obtained in this study were significantly greater than the results obtained in previous work with this same modality, despite the fact that the frequency of training was lower [16]. These improvements could be linked to the rigorousness with which the intensity and volume of strength training was quantified, which provided the same training for all participants and a similar degree of exertion [25,26,28–30]. The greater changes in the combined training groups can be attributed to an improvement in endothelial function induced by strength training. Endothelial dysfunction is associated with several cardiovascular risk factors, including hypertension. The endothelium plays an important role in vascular contractile modulation that is largely dependent on the bioavailability of nitric oxide (NO) [60–62]. When the endothelium is damaged, it neutralizes NO production and stimulates the production of vasoconstrictive substances, leading to an increase in blood pressure [63,64]. Strength training can stimulate NO production by increasing vascular AMPK/PPARδ and suppressing endoplasmic reticulum stress, thereby improving endothelial function [65–68]. Furthermore, although the two combined training groups had the same dose of strength training, the group that performed MICT showed greater improvements than the group that performed HIIT. This may be because aerobic exercise, performed over a prolonged period of time and at a moderate intensity, has been widely shown to have beneficial effects on endothelial function [69,70].

In terms of body composition variables, lean mass and waist circumference, the intervention groups showed significant improvements, while the CG showed no change. Physical exercise induces changes in body composition because during muscle contraction, hundreds of exerkines with autocrine, paracrine or endocrine effects are released into the bloodstream, with major health benefits [4,71,72]. Training can increase muscle mass and reduce fat percentage [68,72], as the secretion of some of these exerkines promotes muscle hypertrophy and myogenesis, lipolysis, and fatty acid oxidation, and induces the browning of white adipose tissue [68,72–74]. Likewise, the participants in the strength training groups showed the most improvement in these variables, with the combined MICT group again showing the most improvement. These results can be attributed to strength training, which promotes visceral fat loss by promoting metabolic adaptations in the abdominal subcutaneous adipose tissue, with a significant increase in lipolysis in this area, both during and after training [72,75,76]. With regard to improvements in body composition, it is known that muscle is an important modifiable risk factor for the development of cardiovascular disease, also for cardiovascular disease mortality and for all-cause mortality; lean mass appears to have a protective effect against cardiovascular and metabolic disease [77]. On the other hand, recent studies have compared improvements in body composition with MICT vs HIIT training, showing that the changes brought about by both types of training are similar and even favor MICT in reducing body fat [78–80].

In line with these changes, it can be observed that participants in the intervention groups also significantly reduced their total cholesterol, LDL and glucose values, with these reductions being significantly different from the CG, which did not change. These improvements can be brought about by the release of IL-6 during exercise, among other exerkines, as its signaling within muscle leads to an increase in basal glucose uptake and translocation of its transporter GLUT-4 [68,72,81], in addition to increasing intramyocellular or whole-body fatty acid oxidation through activation of AMPK [68,72,81].

In relation to physical fitness, the results showed significant improvements in all three training groups in both strength and cardiorespiratory fitness as compared to the CG. Regarding the strength gains of the three intervention groups, it is known that the practice of exercise, regardless of the modality performed, is capable of provoking structural (peripheral) and neural (central) physiological adaptations, as muscular action is necessary to overcome a load [25,26]. The central adaptations of these groups were determined by the type of activity performed, the intensity of the work, and the duration of the action [25]. The combined strength training group with MICT showed greater improvements in manual pressure strength and maximal upper and lower limb strength than the continuous moderate-intensity group. These results may be a response to strength training, which achieves greater neural adaptations through increased recruitment and synchronization of motor units and stimulus frequency, as previously demonstrated in the literature [82–84]. These adaptations of the central nervous system as a whole contribute to gains and improvements in maximal strength. In terms of aerobic endurance, the results revealed significant changes in the function of the cardiovascular and respiratory systems, with an improvement observed in maximal oxygen consumption and an increase in stroke volume and cardiac output. Exercise can lead to important adaptations in skeletal muscle, such as increased mitochondrial biogenesis and capillary density, with these responses to exercise reflected in an improved ability to transport and use oxygen to generate energy [85–87]. Many studies support the important role of PGC-1α (peroxisome proliferator-activated receptor gamma 1α coactivator) in these muscle adaptations induced by aerobic endurance exercise, including its possible role in the complex regulation of mitochondrial quality [86,59,88]. Despite the controversy that combined training may interfere with the adaptations induced by the different metabolic pathways AMPK and m-TOR, activated by aerobic and strength training respectively, in the present study, it can be observed that EG2, strength training combined with MICT, obtained greater improvements in VO_2peak than EG1, which performed a single modality of continuous moderate-intensity training, showing the compatibility of the two modalities in the same session and showing a similarity with previous studies [89,90]. These results can be justified by the large adaptive reserve that sedentary subjects have at the start of any exercise program. Previous studies have shown that sedentary subjects who begin a combined strength and endurance training program achieve a positive and additive response to the two exercise modalities, favoring a generic adaptation in the absence of a true specificity of the training effect [91]. Another important factor to consider is the low degree of fatigue in strength training, which could explain the possible interference of this training modality, thus achieving a greater maintenance of the MHC IIX

Table 2
Effect of multicomponent training and cardiovascular training on blood biomarkers and body composition.

Outcome	Group	Pre-test (M±SD)	Post-test (M±SD)	No Adjusted			Group* time interaction		
				Difference post-pre (M± SD)	p	95 % CI (Mpost-Mpre)	F	Sig	ES
SBP (mmHg)	EG1	144.46 ± 8.83	136.17 ± 7.86	−8.29 ± 1.46[a,e,d]	<0.001	−11.20; −5.38	36.00	<0.001	0.54
	EG2	143.44 ± 7.53	121.76 ± 8.52	−21.68 ± 1.43[a,b,e,d]	<0.001	−24.53; −18.82			
	EG3	143.87 ± 8.49	128.96 ± 10.40	−14.91 ± 1.49[a,b,e]	<0.001	−17.88; −11.94			
	CG	147.92 ± 11.83	146.56 ± 11.52	−1.36 ± 1.43[b,e,d]	0.346	−4.21; 1.49			
DBP (mmHg)	EG1	90.00 ± 6.90	82.92 ± 6.12	−7.08 ± 1.10[a,e]	<0.001	−9.27; −4.89	19.46	<0.001	0.38
	EG2	88.28 ± 5.72	74.36 ± 5.09	−13.92 ± 1.08[a,b]	<0.001	−16.06; −11.77			
	EG3	88.30 ± 6.98	77.61 ± 7.91	−10.69 ± 1.12[a]	<0.001	−12.93; −8.45			
	CG	92.16 ± 7.28	89.32 ± 6.95	−2.84 ± 1.08[b,e,d]	0.01	−4.98; −0.69			
MAP (mmHg)	EG1	108.17 ± 5.96	100.67 ± 5.87	−7.50 ± 1.00[a,e,d]	<0.001	−9.49; −5.50	37.06	<0.001	0.54
	EG2	106.52 ± 5.27	90.12 ± 5.34	−16.40 ± 0.98[a,b,e]	<0.001	−18.35; −14.44			
	EG3	106.78 ± 6.90	94.74 ± 7.85	−12.04 ± 1.02[a,b,e]	<0.001	−14.08; −10.00			
	CG	110.60 ± 7.25	108.28 ± 7.80	−2.32 ± 0.98[b,e,d]	0.021	−4.27; −0.36			
PP (mmHg)	EG1	54.46 ± 10.29	53.25 ± 6.72	−1.20 ± 1.49[e]	0.419	−4.16; 1.75	7.84	<0.001	0.20
	EG2	55.16 ± 7.48	47.40 ± 7.68	−7.76 ± 1.46[a,b]	<0.001	−10.65; −4.86			
	EG3	55.54 ± 6.17	50.83 ± 9.58	−4.73 ± 1.52[a]	0.002	−7.76;-1.71			
	CG	55.76 ± 11.32	57.20 ± 8.51	1.44 ± 1.46[e,d]	0.327	−1.45; 4.33			
RPP	EG1	11379.67 ± 1442.92	10005.00 ± 1365.80	−1374.66 ± 251.81[e,d]	<0.001	−1874.71; −874.61	22.88	<0.001	0.42
	EG2	11254.00 ± 1735.96	8507.64 ± 1309.88	−2746.36 ± 246.72[b,d]	<0.001	−3236.30; −2256.41			
	EG3	11545.13 ± 1554.06	9528.30 ± 1474.82	−2016.82 ± 257.23[a,b,e]	<0.001	−2527.63; −1506.01			
	CG	11827.56 ± 1474.97	11875.68 ± 1132.23	48.12 ± 246.72[ee]	0.846	−441.82; 538.06			
RHR	EG1	79.04 ± 11.20	73.54 ± 9.51	−5.50 ± 1.64[a]	0.001	−8.77; −2.23	7.02	<0.001	0.18
	EG2	78.40 ± 11.05	69.72 ± 8.49	−8.68 ± 1.61[a]	<0.001	−11.88; −5.47			
	EG3	80.17 ± 8.95	73.57 ± 9.38	−6.60 ± 1.68[a]	<0.001	−9.94; −3.26			
	CG	80.00 ± 8.23	81.28 ± 8.06	1.28 ± 1.61[b,e,d]	0.430	−1.92; 4.48			
Weight (Kg)	EG1	91.45 ± 16.59	91.32 ± 16.45	−0.20 ± 0.16	0.212	−0.53; 0.12	0.73	0.531	0.24
	EG2	78.11 ± 14.18	77.75 ± 13.89	−0.17 ± 0.16	0.282	−0.49; 0.14			
	EG3	87.88 ± 16.01	86.98 ± 16.62	−0.40 ± 0.16	0.019	−0.74; −0.68			
	CG	88.94 ± 15.94	88.86 ± 16.28	−0.04 ± 0.16	0.806	−0.36; 0.28			
LBM (Kg)	EG1	30.28 ± 6.34	30.77 ± 6.31	−0.12 ± 0.38[a]	0.756	−0.89; 0.64	0.76	0.514	0.24
	EG2	28.98 ± 6.73	29.56 ± 6.77	−0.35 ± 0.37[a]	0.351	−1.11; 0.39			
	GE3	29.93 ± 5.77	30.38 ± 6.21	−0.89 ± 0.39[a]	0.026	−1.68; −0.11			
	CG	30.56 ± 5.98	30.38 ± 5.92	−0.08 ± 0.37[b,e,d]	0.825	−0.83; 0.67			
BFP (%)	EG1	39.70 ± 8.09	38.73 ± 8.20	−0.96 ± 0.33	0.004	−1.62; −0.30	3.78	0.013	0.11
	EG2	32.62 ± 10.27	31.55 ± 9.75	−1.07 ± 0.32	0.001	−1.71; −0.42			
	EG3	38.00 ± 9.08	36.83 ± 9.15	−1.17 ± 0.33[a]	0.001	−1.84; −0.49			
	CG	37.69 ± 8.44	37.89 ± 8.70	0.19 ± 0.32[d]	0.547	−0.44; 0.84			
BMI (Kg/m^2)	EG1	32.61 ± 5.14	32.40 ± 5.11	−0.90 ± 0.39	0.024	−1.68; −0.12	3.23	0.026	0.09
	EG2	27.43 ± 4.87	27.25 ± 4.56	−1.09 ± 0.38	0.006	−1.85; −0.32			
	EG3	31.85 ± 5.59	31.44 ± 5.56	−1.46 ± 0.40	<0.001	−2.26, −0.66			
	EG	31.90 ± 4.99	31.86 ± 5.09	0.18 ± 0.38	0.628	−0.57; 0.95			
VF (cm^2)	EG1	183.60 ± 59.58	178.39 ± 59.24	−5.21 ± 2.12	0.016	−9.42; −0.99	3.32	0.023	0.09
	EG2	125.19 ± 58.83	119.74 ± 54.32	−5.44 ± 2.07	0.010	−9.57; −1.31			
	EG3	165.07 ± 56.86	156.66 ± 56.29	−8.41 ± 2.16[a]	<0.001	−12.71; −4.10			
	CG	165.25 ± 54.58	166.10 ± 55.82	0.84 ± 2.07[d]	0.684	−3.28; 4.97			
Waist circumference (cm)	EG1	110.08 ± 13.26	106.83 ± 15.27	−3.25 ± 0.88[a,e]	<0.001	−5.00; −1.49	12.66	<0.001	0.29
	EG2	98.76 ± 10.54	92.16 ± 10.58	−6.60 ± 0.86[a,b]	<0.001	−8.32; −4.87			
	EG3	106.60 ± 14.32	102.26 ± 16.12	−4.34 ± 0.90[a]	<0.001	−6.14; −2.55			
	CG	105.80 ± 12.33	106.52 ± 12.64	0.72 ± 0.86[b,e,d]	0.409	−1.00; 2.44			

Legend: SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; MAP: Mean Arterial Pressure; PP: Pulse Pressure: RPP: Rate Pressure Product; RHR: Resting Heart Rate; BMI: Body Mass Index; LBM: Lean Body Mass; BFP: Body Fat Percentage; VF: Visceral Fat.

[a] Significantly different from corresponding CG value at the $p < 0.05$ level.
[b] Significantly different from corresponding EG1 value at the $p < 0.05$ level.
[e] Significantly different from corresponding EG2 value at the $p < 0.05$ level.
[d] Significantly different from corresponding EG3 value at the $p < 0.05$ level.

fibers [92].

This study has some limitations that should be taken into account for future research, such as the total intervention time. It is possible that longer periods of time training will lead to more significant results in some of the variables. Another point to consider is an intervention group with only strength training that could have been compared with the other modalities, and the effects on blood pressure as compared to the other modalities could have been known more precisely. Finally, another limitation was the daily intake of the participants, as the diet could have been controlled by making a daily dietary record.

Despite these limitations, this would be the first study in a hypertensive population comparing different strength training modalities, based on an individual assessment of the load-velocity relationship, combined with MICT and HIIT, versus continuous moderate-high intensity training. Another contribution and strength of this study is the precision with which the effort was dosed through the speed of execution, which allowed the workload to be individualized for each participant, ensuring that the stimulus programmed for strength training was truly the one applied and executed by each of them. More importantly, this quantification of load allowed all hypertensive participants to perform the same training and reach a similar degree of fatigue.

Table 3
Effect of multicomponent training and cardiovascular training on metabolic biomarkers, and physical fitness.

Outcome	Group	Pre-test (M ± ED)	Post-test (M ± ED)	No Adjusted			Group[a] time interaction		
				Difference post-pre (M± ED)	p	95 % CI (Mpost-Mpre)	F	Sig	ES
TC (mg/dl)	EG1	192.25 ± 40.54	185.04 ± 23.10	−7.20 ± 5.43[a]	0.18	−18.00; 3.58	7.34	<0.001	0.19
	EG2	199.72 ± 30.11	192.08 ± 29.20	−7.64 ± 5.32[a]	0.15	−18.21; 2.93			
	EG3	195.73 ± 38.36	177.16 ± 35.48	−18.47 ± 5.54[a]	0.001	−29.50; −7.45			
	CG	191.76 ± 28.50	208.00 ± 29.89	16.24 ± 5.32[b,c,d]	0.003	5.66; 26.81			
HDL (mg/dl)	EG1	48.21 ± 7.15	50.00 ± 10.37	1.79 ± 1.00	0.078	−0.20; 3.79	0.89	0.447	0.02
	EG2	54.44 ± 9.92	55.32 ± 11.29	0.88 ± 0.98	0.375	−1.07; 2.83			
	EG3	48.17 ± 11.63	49.17 ± 12.30	1.00 ± 1.02	0.333	−1.04; 3.04			
	CG	48.76 ± 11.09	48.48 ± 12.48	−0.28 ± 0.98	0.777	−2.23; 1.67			
LDL (mg/dl)	EG1	118.27 ± 36.36	110.45 ± 21.58	−7.82 ± 4.71[a]	0.100	−17.18; 1.53	6.65	<0.001	0.17
	EG2	120.61 ± 24.77	114.14 ± 24.54	−6.47 ± 4.61[a]	0.164	−15.64; 2.70			
	EG3	118.15 ± 36.26	105.30 ± 32.60	−12.85 ± 4.81[a]	0.009	−22.41; −3.29			
	CG	116.82 ± 23.25	131.34 ± 31.29	14.52 ± 4.61[b,c,d]	0.002	5.34; 23.69			
TG (mg/dl)	EG1	126.08 ± 52.16	121.91 ± 36.94	−4.16 ± 7.42	0.576	−18.91; 10.58	3.01	0.034	0.09
	EG2	122.32 ± 59.16	113.72 ± 43.21	−8.60 ± 7.27	0.240	−23.05; 5.85			
	EG3	137.21 ± 55.82	121.43 ± 65.24	−15.78 ± 7.58[a]	0.040	−30.84; −0.71			
	CG	133.44 ± 64.33	147.96 ± 79.97	14.52 ± 7.27[d]	0.049	0.70; 28.97			
Glucose (mg/dl)	EG1	107.33 ± 13.49	99.91 ± 14.06	−7.41 ± 1.60[a]	<0.001	−10.60; −4.22	11.73	<0.001	0.27
	EG2	98.16 ± 14.69	91.36 ± 10.77	−6.80 ± 1.57[a]	<0.001	−9.92; −3.67			
	EG3	97.60 ± 13.05	87.65 ± 13.14	−9.95 ± 1.64[a]	<0.001	−13.21; −6.69			
	CG	97.24 ± 22.48	99.80 ± 19.94	2.56 ± 1.57[b,c,d]	0.107	−0.56; 5.68			
Handgrip RA	EG1	32.85 ± 7.61	35.56 ± 10.23	2.70 ± 0.59[a]	<0.001	1.53; 3.88	7.91	<0.001	0.20
	EG2	31.18 ± 9.80	33.24 ± 11.18	2.06 ± 0.57	0.001	0.91; 3.20			
	EG3	31.80 ± 7.79	35.45 ± 8.26	3.65 ± 0.60[a]	0.80	2.45; 4.84			
	CG	31.42 ± 8.73	31.56 ± 8.81	0.14 ± 0.57[b,d]	<0.001	−1.00; 1.28			
1RM (Kg UL)	EG1	51.33 ± 21.18	59.87 ± 24.99	8.54 ± 1.58[a,c]	<0.001	5.40; 11.68	41.34	<0.001	0.57
	EG2	46.24 ± 23.68	65.12 ± 30.34	18.88 ± 1.54[a,b,d]	<0.001	15.80; 21.95			
	EG3	51.09 ± 20.52	62.78 ± 26.91	11.69 ± 1.61[b,c]	<0.001	8.48; 14.90			
	CG	54.24 ± 24.26	52.20 ± 23.20	−2.04 ± 1.54[b,c,d]	0.191	−5.11; 1.03			
MPV (m/s 50 %)	EG1	0.97 ± 0.02	1.08 ± 0.07	0.10 ± 0.01[a,c]	<0.001	0.08; 0.13	78.17	<0.001	0.71
	EG2	0.96 ± 0.03	1.20 ± 0.06	0.23 ± 0.01[a,b,c,d]	<0.001	0.20; 0.26			
	EG3	0.96 ± 0.03	1.10 ± 0.06	0.13 ± 0.01[a,c]	<0.001	0.10; 0.16			
	CG	0.97 ± 0.02	0.92 ± 0.04	−0.05 ± 0.01[b,c,d]	<0.001	−0.07; −0.02			
1RM (Kg LL)	EG1	70.75 ± 34.09	87.96 ± 38.71	17.20 ± 1.92[b,c]	<0.001	13.38; 21.03	49.49	<0.001	0.61
	EG2	73.08 ± 35.11	98.32 ± 41.42	25.24 ± 1.88[a,b]	<0.001	21.49; 28.98			
	EG3	79.26 ± 32.24	97.65 ± 37.24	18.39 ± 1.96[b]	<0.001	14.48; 22.29			
	CG	79.92 ± 32.17	76.44 ± 30.72	−3.48 ± 1.88[b,c,d]	0.068	−7.22; 0.26			
MPV (m/s 60 %)	EG1	0.99 ± 0.02	1.15 ± 0.08	0.16 ± 0.01[a,c]	<0.001	0.13; 0.19	76.50	<0.001	0.71
	EG2	0.99 ± 0.02	1.21 ± 0.05	0.22 ± 0.01[a,b]	<0.001	0.19; 0.25			
	EG3	0.98 ± 0.02	1.16 ± 0.06	0.17 ± 0.01[a]	<0.001	0.14; 0.20			
	CG	0.99 ± 0.02	0.95 ± 0.05	−0.03 ± 0.01[b,c,d]	0.006	−0.06; −0.01			
VO2p (ml/kg/min)	EG1	22.01 ± 4.34	26.71 ± 5.38	4.69 ± 0.34[a]	<0.001	4.00; 5.38	57.55	<0.001	0.65
	EG2	25.08 ± 3.82	30.86 ± 4.40	5.78 ± 0.33[a,d]	<0.001	5.10; 6.45			
	EG3	21.13 ± 3.64	24.56 ± 4.56	3.43 ± 0.35[a,c]	<0.001	2.73, 4.13			
	CG	21.61 ± 3.58	21.43 ± 3.57	−0.18 ± 0.33[b,c,d]	0.588	−0.85; 0.49			

Legend: TC: Total Cholesterol; HDL: High Density Lipoprotein; LDL: Low Density Lipoprotein; TG: Triglycerides; RA: right arm; LA: left arm; 1RM: One-Repetition Maximum; UL: Upper Limb; LL: Lower Limb; MPV: mean propulsive velocity; VO2p: Peak oxygen consumption.

[a] Significantly different from corresponding CG value at the $p < 0.05$ level.
[b] Significantly different from corresponding EG1 value at the $p < 0.05$ level.
[c] Significantly different from corresponding EG2 value at the $p < 0.05$ level.
[d] Significantly different from corresponding EG3 value at the $p < 0.05$ level.

5. Conclusion

The results of the present study indicate that the implementation of a strength training program, based on an individual assessment of the load-velocity relationship, combined with MICT in the same session, 2 days per week for 12 weeks, produces significant improvements in blood and metabolic biomarkers, body composition, and physical condition, in adults with hypertension, with these adaptations being superior to those produced by MICT and strength training combined with HIIT, which also show improvements, but to a lesser extent.

CRediT authorship contribution statement

Isabel López-Ruiz: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Fernando Lozano Ruiz-Poveda:** Writing – review & editing, Funding acquisition. **María Dolores Masía:** Writing – review & editing, Visualization, Conceptualization. **Juan Ramón Heredia-Elvar:** Writing – review & editing, Visualization. **Noelia González-Gálvez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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References

[1] M. Vaduganathan, G.A. Mensah, J.V. Turco, V. Fuster, G.A. Roth, The global burden of cardiovascular diseases and risk: a compass for future health, J. Am. Coll. Cardiol. 80 (25) (2022) 2361–2371.
[2] G.A. Mensah, V. Fuster, C.J.L. Murray, G.A. Roth, Global burden of cardiovascular diseases and risks, 1990-2022, J. Am. Coll. Cardiol. 82 (25) (2023) 2350–2473.
[3] G. Mancia, R. Kreutz, M. Brunström, M. Burnier, G. Grassi, A. Januszewicz, et al., 2023 ESH guidelines for the management of arterial hypertension the task force for the management of arterial hypertension of the European society of hypertension: endorsed by the international society of hypertension (ISH) and the European renal association (ERA), J. Hypertens. 41 (12) (2023) 1874–2071.
[4] B.K. Pedersen, B. Saltin, Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases, Scand. J. Med. Sci. Sports 25 (Suppl 3) (2015) 1–72.
[5] H. Momma, R. Kawakami, T. Honda, S.S. Sawada, Muscle-strengthening activities are associated with lower risk and mortality in major non-communicable diseases: a systematic review and meta-analysis of cohort studies, Br. J. Sports Med. 56 (13) (2022) 755–763.
[6] A. Pelliccia, S. Sharma, S. Gati, M. Bäck, M. Börjesson, S. Caselli, et al., 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease: the Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC), Eur. Heart J. 42 (1) (2020) 17–96.
[7] F.J. Charchar, P.R. Prestes, C. Mills, S.M. Ching, D. Neupane, F.Z. Marques, et al., Lifestyle management of hypertension: international society of hypertension position paper endorsed by the world hypertension league and European society of hypertension, J. Hypertens. 42 (1) (2024) 23–49.
[8] P.K. Whelton, R.M. Carey, W.S. Aronow, D.E. Casey Jr., K.J. Collins, C. Dennison Himmelfarb, et al., 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary: a report of the American college of cardiology/American heart association task force on clinical practice guidelines, Circulation 138 (17) (2018) e426–e483.
[9] H. Hanssen, H. Boardman, A. Deiseroth, T. Moholdt, M. Simonenko, N. Kränkel, et al., Personalized exercise prescription in the prevention and treatment of arterial hypertension: a consensus document from the European association of preventive cardiology (EAPC) and the ESC council on hypertension, Eur. J. Prev. Cardiol. 29 (1) (2021) 205–215.
[10] L.A. Kaminsky, C.J. Lavie, K. Flint, R. Arena, S. Bond, Working toward optimal exercise prescription: strength training should not Be overlooked, J Cardiopulm Rehabil Prev 42 (2) (2022). E32-e3.
[11] S. Masroor, P. Bhati, S. Verma, M. Khan, M.E. Hussain, Heart rate variability following combined aerobic and resistance training in sedentary hypertensive women: a randomised control trial, Indian Heart J. 70 (3) (2018) S28–s35. Suppl 3.
[12] L.G. Lima, J.T.M. Bonardi, G.O. Campos, R.F. Bertani, L.M.L. Scher, J.C. Moriguti, et al., Combined aerobic and resistance training: are there additional benefits for older hypertensive adults? Clinics 72 (6) (2017) 363–369.
[13] G.V. Guimarães, L.G. de Barros Cruz, M.M. Fernandes-Silva, E.L. Dorea, E. A. Bocchi, Heated water-based exercise training reduces 24-hour ambulatory blood pressure levels in resistant hypertensive patients: a randomized controlled trial (HEx trial), Int. J. Cardiol. 172 (2) (2014) 434–441.
[14] E.S. Dos Santos, R.Y. Asano, I.G. Filho, N.L. Lopes, P. Panelli, C. Nascimento Dda, et al., Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: a randomized controlled trial, J. Strength Condit Res. 28 (11) (2014) 3073–3084.
[15] V.M. Schneider, L.B. Domingues, D. Umpierre, H. Tanaka, R. Ferrari, Exercise characteristics and blood pressure reduction after combined aerobic and resistance training: a systematic review with meta-analysis and meta-regression, J. Hypertens. 41 (7) (2023) 1068–1076.
[16] I. López-Ruiz, F. Lozano, M.D. Masia, N. González-Gálvez, Multicomponent training and optimal dosing strategies for adults with hypertension: a systematic review and meta-analysis of randomized controlled trials, Sports 11 (6) (2023).
[17] H. Albalawi, E. Coulter, N. Ghouri, L. Paul, The effectiveness of structured exercise in the south Asian population with type 2 diabetes: a systematic review, Physician Sportsmed. 45 (4) (2017) 408–417.
[18] K.L. Way, R.N. Sultana, A. Sabag, M.K. Baker, N.A. Johnson, The effect of high Intensity interval training versus moderate intensity continuous training on arterial stiffness and 24h blood pressure responses: a systematic review and meta-analysis, J. Sci. Med. Sport 22 (4) (2019) 385–391.
[19] L. Li, X. Liu, F. Shen, N. Xu, Y. Li, K. Xu, et al., Effects of high-intensity interval training versus moderate-intensity continuous training on blood pressure in patients with hypertension: a meta-analysis, Medicine (Baltim.) 101 (50) (2022) e32246.
[20] E.C. Costa, J.L. Hay, D.S. Kehler, K.F. Boreskie, R.C. Arora, D. Umpierre, et al., Effects of high-intensity interval training versus moderate-intensity continuous training on blood pressure in adults with pre- to established hypertension: a systematic review and meta-analysis of randomized trials, Sports Med. 48 (9) (2018) 2127–2142.
[21] J.S. Ramos, L.C. Dalleck, A.E. Tjonna, K.S. Beetham, J.S. Coombes, The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: a systematic review and meta-analysis, Sports Med. 45 (5) (2015) 679–692.
[22] L. Carpes, R. Costa, B. Schaarschmidt, T. Reichert, R. Ferrari, High-intensity interval training reduces blood pressure in older adults: a systematic review and meta-analysis, Exp. Gerontol. 158 (2022) 111657.
[23] C. Alvarez, L. Peñailillo, P. Ibacache-Saavedra, D. Jerez-Mayorga, C. Campos-Jara, D.C. Andrade, et al., Six weeks of a concurrent training therapy improves endothelial function and arterial stiffness in hypertensive adults with minimum non-responders, Hipertens. Riesgo Vasc. (2024).
[24] S.S. Kazemi, A. Heidarianpour, E. Shokri, Effect of resistance training and high-intensity interval training on metabolic parameters and serum level of Sirtuin1 in postmenopausal women with metabolic syndrome: a randomized controlled trial, Lipids Health Dis. 22 (1) (2023) 177.
[25] J.J.G. Badillo, J.R. Serna, Bases de la programación del entrenamiento de fuerza: Inde, 2002.
[26] J.J. González-Badillo, L. Sánchez-Medina, J. Ribas-Serna, D. Rodríguez-Rosell, Toward a new paradigm in resistance training by means of velocity monitoring: a critical and challenging narrative, Sports Med Open 8 (1) (2022) 118.
[27] D. Rodríguez-Rosell, J.M. Yáñez-García, L. Sánchez-Medina, R. Mora-Custodio, J. J. González-Badillo, Relationship between velocity loss and repetitions in reserve in the bench press and back squat exercises, J. Strength Condit Res. 34 (9) (2020) 2537–2547.
[28] J.J. González-Badillo, L. Sánchez-Medina, Movement velocity as a measure of loading intensity in resistance training, Int. J. Sports Med. 31 (5) (2010) 347–352.
[29] L. Sánchez-Medina, J.J. González-Badillo, Velocity loss as an indicator of neuromuscular fatigue during resistance training, Med. Sci. Sports Exerc. 43 (9) (2011) 1725–1734.
[30] J.J.G. Badillo, La velocidad de ejecución como referencia para la programación, control y evaluación del entrenamiento de fuerza: Ergotech, 2017.
[31] L. Andreu-Caravaca, D.J. Ramos-Campo, O. Abellán-Aynés, J. Rubio-Arias, Movement velocity as A measure of exercise intensity in persons with multiple sclerosis: a validity study, J. Clin. Med. 9 (8) (2020).
[32] P.J. Marcos-Pardo, J.M. González-Hernández, A. García-Ramos, A. López-Vivancos, P. Jiménez-Reyes, Movement velocity can be used to estimate the relative load during the bench press and leg press exercises in older women, PeerJ 7 (2019) e7533.
[33] D.M. Díez-Fernández, A. Baena-Raya, A. García-Ramos, A. Esteban-Simón, M. A. Rodríguez-Pérez, A.J. Casimiro-Andújar, et al., Estimating the one-repetition maximum on the leg-press exercise in female breast cancer survivors, PeerJ 11 (2023) e16175.
[34] E.C. Schroeder, W.D. Franke, R.L. Sharp, D.C. Lee, Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: a randomized controlled trial, PLoS One 14 (1) (2019) e0210292.
[35] M. Gorostidi, T. Gijón-Conde, A. De la Sierra, E. Rodilla, E. Rubio, E. Vinyoles, et al., Guía práctica sobre el diagnóstico y tratamiento de la hipertensión arterial en España, 2022. Sociedad Española de Hipertensión-Liga Española para la Lucha contra la Hipertensión Arterial (SEH-LELHA), Hipertens. Riesgo Vasc. 39 (4) (2022) 174–194.
[36] K.J. Stewart, A.C. Bacher, K.L. Turner, J.L. Fleg, P.S. Hees, E.P. Shapiro, et al., Effect of exercise on blood pressure in older persons: a randomized controlled trial, Arch. Intern. Med. 165 (7) (2005) 756–762.
[37] A. Buch, A. Ben-Yehuda, V. Rouach, A.B. Maier, Y. Greenman, E. Izkhakov, et al., Validation of a multi-frequency bioelectrical impedance analysis device for the assessment of body composition in older adults with type 2 diabetes, Nutr. Diabetes 12 (1) (2022) 45.
[38] Y. Lahav, N. Goldstein, Y. Gepner, Comparison of body composition assessment across body mass index categories by two multifrequency bioelectrical impedance analysis devices and dual-energy X-ray absorptiometry in clinical settings, Eur. J. Clin. Nutr. 75 (8) (2021) 1275–1282.
[39] M. Marfell Jones, T. Olds, A. Stewart, L. Carter, Sociedad Internacional para el Avance de la Cineantropometría (ISAK), Manual ISAK, 2006.
[40] ESo Hypertension, Automated devices for clinical use, Dabl Educational Trust, resting cuff sizes 16–24 (2010) 22–32, and 31-45 cm.
[41] G.S. Stergiou, P. Palatini, G. Parati, E. O'Brien, A. Januszewicz, E. Lurbe, et al., 2021 European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement, J. Hypertens. 39 (7) (2021) 1293–1302.
[42] V. Mathiowetz, N. Kashman, G. Volland, K. Weber, M. Dowe, S. Rogers, Grip and pinch strength: normative data for adults, Arch. Phys. Med. Rehabil. 66 (2) (1985) 69–74.
[43] J.J. González-Badillo, J.M. Yañez-García, R. Mora-Custodio, D. Rodríguez-Rosell, Velocity loss as a variable for monitoring resistance exercise, Int. J. Sports Med. 38 (3) (2017) 217–225.
[44] L. Sánchez-Medina, J.G. Pallarés, C.E. Pérez, R. Morán-Navarro, J.J. González-Badillo, Estimation of relative load from bar velocity in the full back squat exercise, Sports Medicine Int. Open 1 (2) (2017) E80–E88.
[45] R.F. Escamilla, Knee biomechanics of the dynamic squat exercise, Med. Sci. Sports Exerc. 33 (1) (2001) 127–141.
[46] F. Conceição, J. Fernandes, M. Lewis, J.J. González-Badillo, P. Jiménez-Reyes, Movement velocity as a measure of exercise intensity in three lower limb exercises, J. Sports Sci. 34 (12) (2016) 1099–1106.
[47] D. Rodríguez-Rosell, J.M. Yáñez-García, R. Mora-Custodio, F. Pareja-Blanco, A. G. Ravelo-García, J. Ribas-Serna, et al., Velocity-based resistance training: impact of velocity loss in the set on neuromuscular performance and hormonal response, Appl. Physiol. Nutr. Metabol. 45 (8) (2020) 817–828.

[48] R. Morán-Navarro, A. Martínez-Cava, L. Sánchez-Medina, R. Mora-Rodríguez, J. J. González-Badillo, J.G. Pallarés, Movement velocity as a measure of level of effort during resistance exercise, J. Strength Condit Res. 33 (6) (2019) 1496–1504.

[49] J.R. Gómez-Puerto, M. Edir Da Silva-Grigoletto, B. Hernán Viana-Montaner, D. Vaamonde, J.R. Alvero-Cruz, La importancia de los ajustes de la bicicleta en la prevención de las lesiones en el ciclismo: aplicaciones prácticas, Rev. Andal. Med. Deporte (2008).

[50] P.M. Marqueta, L.F. Bonafonte, J.N. Orellana, D.B. Cuixart, J.C. Nogués, C.C. Soto, et al., Pruebas de esfuerzo en medicina del deporte, Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE). Archivos de medicina del deporte: revista de la Federación Española de Medicina del Deporte y de la Confederación Iberoamericana de Medicina del Deporte 33 (1) (2016) 5–83.

[51] B. Ferguson, ACSM's guidelines for exercise testing and prescription 9th, J. Can. Chiropr. Assoc. 58 (2014) 328. © Jcca 2014.; 2014.

[52] T. Yue, Y. Wang, H. Liu, Z. Kong, F. Qi, Effects of high-intensity interval vs. Moderate-intensity continuous training on cardiac rehabilitation in patients with cardiovascular disease: a systematic review and meta-analysis, Front. Cardiovasc. Med. 9 (2022) 845225.

[53] G.G. Cardozo, R.B. Oliveira, P.T. Farinatti, Effects of high intensity interval versus moderate continuous training on markers of ventilatory and cardiac efficiency in coronary heart disease patients, Sci. World J. 2015 (2015) 192479.

[54] D.E. Warburton, D.C. McKenzie, M.J. Haykowsky, A. Taylor, P. Shoemaker, A. P. Ignaszewski, et al., Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease, Am. J. Cardiol. 95 (9) (2005) 1080–1084.

[55] D. Hansen, A. Abreu, M. Ambrosetti, V. Cornelissen, A. Gevaert, H. Kemps, et al., Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology, European J.Prev. Cardiol. 29 (1) (2021) 230–245.

[56] G. Borg, Borg's Perceived Exertion and Pain Scales, Human kinetics, 1998.

[57] H. Allen, A.R. Coggan, S. McGregor, Training and Racing with a Power Meter, VeloPress, 2019.

[58] W.G. Hopkins, S.W. Marshall, A.M. Batterham, J. Hanin, Progressive statistics for studies in sports medicine and exercise science, Med. Sci. Sports Exerc. 41 (1) (2009) 3–13.

[59] K. Baar, A.R. Wende, T.E. Jones, M. Marison, L.A. Nolte, M. Chen, et al., Adaptations of skeletal muscle to exercise: rapid increase in the transcriptional coactivator PGC-1, FASEB J. 16 (14) (2002) 1879–1886.

[60] K. Node, M. Kitakaze, H. Yoshikawa, H. Kosaka, M. Hori, Reduced plasma concentrations of nitrogen oxide in individuals with essential hypertension, Hypertension 30 (3 Pt 1) (1997) 405–408.

[61] P. Vallance, J. Collier, S. Moncada, Effects of endothelium-derived nitric oxide on peripheral arteriolar tone in man, Lancet 2 (8670) (1989) 997–1000.

[62] A. Gamboa, C. Shibao, A. Diedrich, L. Choi, B. Pohar, J. Jordan, et al., Contribution of endothelial nitric oxide to blood pressure in humans, Hypertension 49 (1) (2007) 170–177.

[63] R.P. Brandes, Endothelial dysfunction and hypertension, Hypertension 64 (5) (2014) 924–928.

[64] E. Schulz, T. Gori, T. Münzel, Oxidative stress and endothelial dysfunction in hypertension, Hypertens. Res. 34 (6) (2011) 665–673.

[65] J. Silva, A.L. Meneses, B.J. Parmenter, R.M. Ritti-Dias, B.Q. Farah, Effects of resistance training on endothelial function: a systematic review and meta-analysis, Atherosclerosis 333 (2021) 91–99.

[66] D. Tian, J. Meng, Exercise for prevention and relief of cardiovascular disease: prognoses, mechanisms, and approaches, Oxid. Med. Cell. Longev. 2019 (2019) 3756750.

[67] F.P. Boeno, T.R. Ramis, S.V. Munhoz, J.B. Farinha, C.E.J. Moritz, R. Leal-Menezes, et al., Effect of aerobic and resistance exercise training on inflammation, endothelial function and ambulatory blood pressure in middle-aged hypertensive patients, J. Hypertens. 38 (12) (2020) 2501–2509.

[68] B.K. Pedersen, M.A. Febbraio, Muscles, exercise and obesity: skeletal muscle as a secretory organ, Nat. Rev. Endocrinol. 8 (8) (2012) 457–465.

[69] X. Tao, Y. Chen, K. Zhen, S. Ren, Y. Lv, L. Yu, Effect of continuous aerobic exercise on endothelial function: a systematic review and meta-analysis of randomized controlled trials, Front. Physiol. 14 (2023) 1043108. Switzerland: Copyright © 2023 Tao, Chen, Zhen, Ren, Lv and Yu.

[70] Q. You, L. Yu, G. Li, H. He, Y. Lv, Effects of different intensities and durations of aerobic exercise on vascular endothelial function in middle-aged and elderly people: a meta-analysis, Front. Physiol. 12 (2021) 803102.

[71] D. Di Raimondo, G. Musiari, G. Miceli, V. Arnao, A. Pinto, Preventive and therapeutic role of muscle contraction against chronic diseases, Curr. Pharm. Des. 22 (30) (2016) 4686–4699.

[72] M.C.K. Severinsen, B.K. Pedersen, Muscle-organ crosstalk: the emerging roles of myokines, Endocr. Rev. 41 (4) (2020) 594–609.

[73] B.K. Pedersen, The anti-inflammatory effect of exercise: its role in diabetes and cardiovascular disease control, Essays Biochem. 42 (2006) 105–117.

[74] M.M. Atakan, Ş.N. Koşar, Y. Güzel, H.T. Tin, X. Yan, The role of exercise, diet, and cytokines in preventing obesity and improving adipose tissue, Nutrients 13 (5) (2021).

[75] M. Khalafi, A. Malandish, S.K. Rosenkranz, A.A. Ravasi, Effect of resistance training with and without caloric restriction on visceral fat: a systemic review and meta-analysis, Obes. Rev. 22 (9) (2021) e13275.

[76] M.A. Wewege, I. Desai, C. Honey, B. Coorie, M.D. Jones, B.K. Clifford, et al., The effect of resistance training in healthy adults on body fat percentage, fat mass and visceral fat: a systematic review and meta-analysis, Sports Med. 52 (2022) 287–300. New Zealand: © 2021. The Author(s), under exclusive licence to Springer Nature Switzerland AG.

[77] S. Carbone, D.L. Kirkman, R.S. Garten, P. Rodriguez-Miguelez, E.G. Artero, D. C. Lee, et al., Muscular strength and cardiovascular disease: an updated state-of-the-art narrative review, J Cardiopulm Rehabil Prev 40 (5) (2020) 302–309.

[78] M. Wewege, R. van den Berg, R.E. Ward, A. Keech, The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis, Obes. Rev. 18 (6) (2017) 635–646.

[79] S.E. Keating, N.A. Johnson, G.I. Mielke, J.S. Coombes, A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity, Obes. Rev. 18 (8) (2017) 943–964.

[80] L.V. Andreato, J.V. Esteves, D.R. Coimbra, A.J.P. Moraes, T. de Carvalho, The influence of high-intensity interval training on anthropometric variables of adults with overweight or obesity: a systematic review and network meta-analysis, Obes. Rev. 20 (1) (2019) 142–155.

[81] B.K. Pedersen, M.A. Febbraio, Muscle as an endocrine organ: focus on muscle-derived interleukin-6, Physiol. Rev. 88 (4) (2008) 1379–1406.

[82] R.M. Enoka, Neural adaptations with chronic physical activity, J. Biomech. 30 (5) (1997) 447–455.

[83] D.G. Sale, Neural adaptation to resistance training, Med. Sci. Sports Exerc. 20 (5 Suppl) (1988) S135–S145.

[84] A. Del Vecchio, A. Casolo, F. Negro, M. Scorcelletti, I. Bazzucchi, R. Enoka, et al., The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding, J. Physiol. 597 (7) (2019) 1873–1887.

[85] F.W. Booth, G.N. Ruegsegger, R.G. Toedebusch, Z. Yan, Endurance exercise and the regulation of skeletal muscle metabolism, Prog Mol Biol Transl Sci 135 (2015) 129–151.

[86] S. Jung, K. Kim, Exercise-induced PGC-1α transcriptional factors in skeletal muscle, Integr. Med.Res. 3 (4) (2014) 155–160.

[87] T. Akimoto, S.C. Pohnert, P. Li, M. Zhang, C. Gumbs, P.B. Rosenberg, et al., Exercise stimulates Pgc-1alpha transcription in skeletal muscle through activation of the p38 MAPK pathway, J. Biol. Chem. 280 (20) (2005) 19587–19593.

[88] J.F. Halling, H. Pilegaard, PGC-1α-mediated regulation of mitochondrial function and physiological implications, Appl. Physiol. Nutr. Metabol. 45 (9) (2020) 927–936.

[89] P.G. Pito, J.R. Cardoso, J. Tufano, D. Guariglia, Effects of concurrent training on 1RM and VO2 in adults: systematic review with meta-analysis, Int. J. Sports Med. 43 (4) (2022) 297–304.

[90] M. Khalafi, M.H. Sakhaei, S.K. Rosenkranz, M.E. Symonds, Impact of concurrent training versus aerobic or resistance training on cardiorespiratory fitness and muscular strength in middle-aged to older adults: a systematic review and meta-analysis, Physiol. Behav. 254 (2022) 113888.

[91] V.G. Coffey, J.A. Hawley, Concurrent exercise training: do opposites distract? J. Physiol. 595 (9) (2017) 2883–2896.

[92] F. Pareja-Blanco, D. Rodríguez-Rosell, L. Sánchez-Medina, J. Sanchis-Moysi, C. Dorado, R. Mora-Custodio, et al., Effects of velocity loss during resistance training on athletic performance, strength gains and muscle adaptations, Scand. J. Med. Sci. Sports 27 (7) (2017) 724–735.

ANEXO 17. Estudio 4. Diseño de programas de entrenamiento combinado individualizado para adultos con hipertensión arterial.

CULTURA, CIENCIA Y DEPORTE

DISEÑO DE PROGRAMAS DE ENTRENAMIENTO COMBINADO INDIVIDUALIZADO PARA ADULTOS CON HIPERTENSIÓN ARTERIAL

DESING OF INDIVIDUALISED COMBINED TRAINING PROGRAMMES FOR ADULTS WITH HYPERTENSION

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Resumen

Actualmente la enfermedad cardiovascular es la causa principal de muerte en el mundo. Entre los factores de riesgo desencadenantes de muerte cardiovascular a nivel mundial se encuentra la hipertensión arterial. En consecuencia, son muchos los planes estratégicos para abordar y mejorar los niveles de presión arterial con el objetivo de frenarla la alta incidencia de mortalidad anual, encontrándose entre estas estrategias los programas de ejercicio físico. Por ello, el objetivo de este trabajo es proporcionar a los profesionales de la salud una guía para poder diseñar correctamente un programa de entrenamiento combinado individualizado efectivo, de fuerza y resistencia aeróbica, con la finalidad de mejorar la salud cardiometabólica de esta población. En el presente trabajo se abordan las actuales recomendaciones sobre prescripción de ejercicio físico en personas con hipertensión, y se aportan consideraciones generales a tener en cuenta para la práctica del mismo. Además, se hace referencia al efecto de los fármacos durante el ejercicio físico y cómo tenerlo presente durante su realización, se describen cuales son las adaptaciones agudas al ejercicio y las recomendaciones para el entrenamiento combinado de resistencia y fuerza en esta población. Por último, se propone un programa de entrenamiento combinado individualizado para personas con hipertensión de 12 semanas de duración con una frecuencia de entrenamiento de 2 días/semana. Para el entrenamiento de fuerza la intensidad será baja-moderada y el volumen será bajo, ambas variables individualizadas a través de la velocidad de ejecución; se relizarán 2 ejercicios, 3 series/ejercicio y en progresión horizontal. Para el entrenamiento de resistencia aeróbica la intensidad será baja progresando a moderada, del 55% al 70% de la FCresv incrementando cada 4 semanas, esta variable será individualizada mediante un test clínico en cicloergómetro; el volumen será de 20 min/sesión en bicicleta estática.

Palabras clave: Presión arterial alta, ejercicio, entrenamiento concurrente, fuerza, resistencia.

Abstract

Cardiovascular disease is currently the leading cause of death worldwide. High blood pressure is one of the risk factors that can trigger cardiovascular disease related deaths worldwide. Consequently, there are many strategic plans to address and improve blood pressure levels, with the aim of slowing down the high incidence of annual mortality, and physical exercise programs are among these strategies. Therefore, the objective of this work is to provide health professionals with a guide to correctly design an effective individualized combined training program for strength and aerobic endurance, with the aim of improving the cardiometabolic health of this population. This work addresses the current recommendations on prescribing physical exercise for people with hypertension, and provides general considerations to consider when practicing it. In addition, a reference is made to the effect of drugs during physical exercise and how to keep this in mind during its performance, and the acute adaptations to exercise and the recommendations for combined resistance and strength training in this population are described. Finally, an individualized combined training program for people with hypertension lasting 12 weeks, with a training frequency of 2 days/week, is proposed. For strength training, the intensity will be low-moderate and the volume will be low, with both variables individualized through the speed of execution; 2 exercises will be performed, 3 sets/exercise and in a horizontal progression. For endurance training, the intensity will be low progressing to moderate, from 55% to 70% of the heart rate reserve (HRR) increasing every 4 weeks, and this variable will be individualized by means of a clinical test on a cycloergometer; the volume will be 20 min/session on a static bicycle.

Keywords: High blood pressure, exercise, concurrent training, strength, endurance.

Introducción

Los últimos estudios epidemiológicos posicionan a la enfermedad cardiovascular como primera causa de muerte en el mundo, con la cardiopatía isquémica en primer lugar, seguida del accidente cerebrovascular. Estos estudios también apuntan que la hipertensión arterial sigue siendo el principal factor de riesgo modificable de muerte cardiovascular a nivel mundial, responsable de más de 10 millones de muertes al año (Mensah et al., 2023; Unger et al., 2020; Vaduganathan et al., 2022). Una de las metas de la Organización Mundial de la Salud (OMS) para 2025, en relación con las enfermedades no transmisibles, es reducir la prevalencia de la hipertensión arterial en un 25% (tomando como re-

ferencia los datos de 2010) (OMS, 2023), pero a día de hoy las cifras de incidencia y mortalidad por dicha enfermedad siguen aumentando.

La hipertensión arterial se considera un trastorno crónico y prácticamente asintomático con una etiología multifactorial sin causa concreta. Se puede diferenciar entre hipertensión primaria y secundaria, la más frecuente es la primaria, que corresponde al 90-95% aproximadamente de los casos; la hipertensión secundaria, mucho menos común, suele presentarse en un 5-10% de los pacientes hipertensos (Rimoldi et al., 2014; Unger et al., 2020). La hipertendión primaria es muy heterogénea y presenta una serie de factores de riesgo intrínsecos (no modificables) por su origen biológico y otros factores extrínsecos (modificables) por su naturaleza ambiental asociados al estilo de vida (Gorostidi et al., 2022). Más del 50% de las personas con hipertensión arterial presentan otros factores de riesgo adicionales como sobrepeso-obesidad, dislipemia, resistencia a la insulina o diabetes tipo II; así como unos hábitos de vida poco saludables, entre los que se encuentra el sedentarismo o una mala alimentación (Menéndez et al., 2016; Unger et al., 2020). Con respecto a la hipertensión secundaria, su etiología se puede clasificar en frecuentes e infrecuentes. Entre las causas frecuentes figuran la enfermedad renal parenquimatosa, la enfermedad renovascular, el hiperaldosteronismo primario, el síndrome de apnea-hipopnea del sueño y la hipertensión inducida por fármacos (Unger et al., 2020; Whelton et al., 2018).

Las últimas guías europeas de cardiología e hipertensión consideran hablar de hipertensión arterial cuando en consulta los niveles de presión arterial sistólica son iguales o superiores a 140 mmHg y/o los niveles de presión arterial diastólica son iguales o superiores a 90 mmHg, aunque los valores de corte para definir hipertensión arterial en el hogar o con dispositivos de registro de 24 horas son mostrar una tensión arterial sistólica igual o superior a 135 mmHg y/o una presión arterial diastólica igual o superior a 85 mmHg (Mancia et al., 2023).

En la actualidad existe suficiente evidencia para justificar que el ejercicio físico actúa como una intervención capaz de prevenir y tratar numerosas enfermedades no trasmisibles, entre ellas se encuentran las enfermedades cardiometabólicas, inmunológicas, neurológicas o incluso enfermedades como el cáncer (Pedersen, 2006; Pedersen & Saltin, 2015). En esta línea de los beneficios para la mejora de la salud y la calidad de vida de las personas que se consiguen a través de las terapias no farmacológicas, se pueden encontrar grandes estudios epidemiológicos donde se ha mostrado una relación inversa entre la incidencia de hipertensión arterial y la práctica de ejercicio físico (Liu et al., 2017; Rijal et al., 2024). Las intervenciones no farmacológicas son claves para la prevención y tratamiento de este trastorno; estas intervenciones requieren cambios en los hábitos y conductas de la vida diaria, como abandonar el sedentarismo y comenzar con la práctica de ejercicio físico de forma habitual (Charchar et al., 2024; Pelliccia et al., 2020; Whelton et al., 2018). En 1989, y por primera vez, la OMS y la Sociedad Internacional de Hipertensión Arterial incluyeron recomendaciones de ejercicio físico entre las medidas no farmacológicas destinadas a la disminución de los valores de la presión arterial (OMS, 1989).

En el ámbito clínico las guías de patología cardiovascular e hipertensión marcan las directrices sobre la prescripción de ejercicio físico a nivel mundial en este tipo de población. Estos documentos internacionales contemplan recomendaciones muy generales para la mejora de la salud cardiovascular (Mancia et al., 2023; Unger et al., 2020; Whelton et al., 2018). El ejercicio de resistencia aeróbica ha sido una modalidad bien estudiada por la comunidad científica y se considera, hasta la fecha, el entrenamiento prioritario para sujetos con hipertensión, por ser la modalidad que mayores beneficios obtiene sobre los niveles de presión arterial, con reducciones de -4,9 a -12 mmHg en presión arterial sistólica y de -3,4 a -5,8 mmHg en presión arterial diastólica (Hanssen et al., 2021; Mancia et al., 2023; Pescatello et al., 2015). El trabajo de fuerza se recomienda como entrenamiento complementario al de resistencia, para que los pacientes se puedan beneficiar de las mejoras que ofrece dicha modalidad, entre esas mejoras reducciones de -3,0 a -4,7 mmHg en presión arterial sistólica y de -3,2 a -3,8 mmHg en presión arterial diastólica (Hanssen et al., 2021; Mancia et al., 2023). El entrenamiento combinado de ambas modalidades, fuerza y resistencia, en la misma sesión de entrenamiento también ofrece grandes beneficios para la salud cardiometabólica, como ya se ha demostrado en estudios previos (Corso et al., 2016; López-Ruiz et al., 2023). Esta modalidad combinada es una buena herramienta para abordar la hipertensión arterial debido a las reducciones significativas que tiene sobre los niveles de presión arterial, de hasta -21,68 mmHg en los niveles de presión arterial sistólica y de hasta -13,92 mmHg en los de presión arterial diastólica, incluso, presenta mayores reducciones que el entrenamiento de resistencia por sí solo, de hasta -12,8 mmHg, -6,8 mmHg respectivamente.

Prescripción de Ejercicio Físico Para la Mejora de la Salud Cardiometabólica en Sujetos Adultos con Hipertensión Arterial

Consideraciones Generales Para la Práctica de Ejercicio Físico

Antes de comenzar con un programa de entrenamiento es importante que el sujeto pase por un reconocimiento médico en el que se realizarán unas pruebas rutinarias recomendadas para sujetos con hipertensión arterial, con ello se podrá descartar un riesgo aumentado de ECV o comorbilidades relevantes y garantizar la seguridad para el desarrollo de los programas de entrenamiento. Las pruebas incluyen: analisis de sangre para medir la hemoglobina glucosilada

(HbA1C), los electrolitos, la creatinina, la tasa de filtración glomerular y el perfil lipídico; analisis de orina para estimar la ratio albúmina:creatinina y comprobar la hematuria mediante una tira reactiva; examinar el fondo de ojo para detectar la presencia de retinopatía hipertensiva; y por último, un electrocardiograma de 12 derivaciones (McEvoy et al., 2024; NICE, 2023; Unger et al., 2020).

Las guías clínicas internacionales de cardiología e hipertensión recomiendan la práctica de ejercicio físico como tratamiento no farmacológico para la mejora y el control de la hipertensión arterial (Charchar et al., 2024; Rabi et al., 2020; Unger et al., 2020; Whelton et al., 2018). Estas pautas recomiendan realizar entrenamiento de resistencia de 150 a 300 min/semana (5-7 días/semana) con intensidad moderada y se puede alternar de 75 a 150 min/semana (2-3 días/semana) con intensidad vigorosa (Charchar et al., 2024; McEvoy et al., 2024; Pelliccia et al., 2020; Rabi et al., 2020). Algunos de estos documentos también recomiendan incorporar de 2 a 3 días por semana entrenamiento de fuerza, como complementario al de resistencia aeróbica, sin profundizar sobre su prescripción (Brook et al., 2013; Charchar et al., 2024; Hanssen et al., 2021; Whelton et al., 2018).

Estos patrones de ejercicio deben ser integrados dentro de una sesión completa de entrenamiento que debe mantener siempre la misma estructura, sea cual sea el programa de ejercicio o disciplina deportiva que se vaya a realizar. La estructura de la sesión se compone de tres fases sólidas y sucesivas, la fase de preparación al entrenamiento o calentamiento, la fase principal y fase de recuperación post-entrenamiento o vuelta a la calma, que garantizan la salud y la mejora del rendimiento del sujeto (Bishop, 2003a, 2003b; Fradkin et al., 2010; McGowan et al., 2015).

Actualmente, las guías clínicas no hacen referencia a todas las fases de esta estructura, centrándose exclusivamente en la fase principal de la sesión (Arnett et al., 2019; Brook et al., 2013; Charchar et al., 2024; Mancia et al., 2023; Pelliccia et al., 2020; Rabi et al., 2020). Antes de comenzar con la fase principal, es necesario realizar una fase preparatoria especifica que aumente de forma gradual la frecuencia cardiaca (FC), la actividad pulmonar y el flujo sanguíneo para incrementar el aporte de oxígeno al organismo en general y a nivel muscular en paticular; que aumente la temperatura de la musculatura implicada mejorando la elasticidad muscular evitando distensiones, desgarros y roturas, así como la viscosidad sinovial para facilitar el deslizamiento de las articulaciones. Una vez terminada la fase principal, es necesario realizar una fase de recuperación post-entrenamiento para volver al estado de reposo de forma gradual. Es importante conocer que la medicación antihipertensiva puede provocar reducciones repentinas y excesivas de la presión arterial después del ejercicio, este periodo de vuelta a la calma debe ser prolongado y controlado (Bishop, 2003a, 2003b; Fradkin et al., 2010; McGowan et al., 2015; Pescatello, 2020; Safran et al., 1989; Taylor et al., 2019; Woods et al., 2007).

Estas directrices generales, en un primer momento, pueden servir de ayuda a los pacientes hipertensos para comenzar a moverse y llevar una vida más activa. Sin embargo, la individualización es uno de los principios básicos del entrenamiento y seleccionar los ejercicios dependiendo de los objetivos y necesidades de cada sujeto, programar de manera precisa la carga de trabajo y utilizar la metodología más adecuada será muy importante para conseguir los mejores resultados (Fleck & Kraemer, 2014; Pescatello, 2020; San-Millán, 2023).

Otras recomendaciones a tener en cuenta en este tipo de población serán, por un lado, evitar la maniobra de Valsalva durante la ejecución técnica de los ejercicios de fuerza; prestar especial atención a los ejercicios de hemisferio superior y/o con los brazos por encima de la cabeza, por la respuesta hipertensiva que provocan; tener cuidado con los ejercicios estáticos y a llegar al fallo muscular, por la dificultad de controlar la maniobra de Valsalva, la respuesta hipertensiva o el riesgo de lesión (Nazir et al., 2024; Williams et al., 2007).

Por otro lado, la indumentaria también será importante para una práctica de ejercicio físico segura. Algunos medicamentos antihipertensivos, betabloqueantes o diuréticos, afectan la capacidad de regular la temperatura corporal durante el ejercicio, sobre todo en ambientes cálidos y/o húmedos, lo que puede provocar una hipoglucemia. El sujeto debe llevar prendas transpirables y cómodas para evitar la sudoración excesiva y lesiones en la piel. Respecto al calzado, será recomendable el uso de zapatillas deportivas. Se deben evitar prendas y fajas efecto sauna que puedan favorecer un sincope (Marcos-Pardo et al., 2021; Pescatello, 2020).

Por último, la hidratación es un factor relevante en este grupo de población tratados con betabloqueantes o diuréticos, antes, durante y después del entrenamiento, para evitar una posible deshidratación (Marcos-Pardo et al., 2021; Pescatello, 2020).

En base a todo lo expuesto, y con el objetivo de prevenir y tratar la hipertensión arterial, se debería desde el ámbito médico animar a los pacientes a buscar ayuda en los profesionales del ejercicio físico para realizar un correcto e individualizado programa de entrenamiento, así como asesoramiento y recomendaciones para el momento de la práctica.

Fármacos Antihipertensivos y Ejercicio Físico

Son muchos los medicamentos disponibles para tartar la hipertensión arterial y los posibles efectos secundarios de estos fármacos deben tenerse en cuenta a la hora de comenzar con un programa de ejercicio físico, dado que pueden afectar a las respuestas fisiológicas (Khalil & Zelster, 2020; Laurent, 2017; Pelliccia et al., 2020):

- Inhibidores de la enzima convertidora de angiotensina (IECA): pueden producir erupción cutánea, pérdida de sabor o tos seca y persistente, pero no afectan la capacidad de realizar ejercicio. No deben ser administrardo a mujeres en edad reproductiva debido a los posibles efectos adversos fetales/neonatales.
- Antagonistas del receptor de la angiotensina II (ARA-II): pueden provocar mareos ocasionales, pero no afectan la capacidad de realizar ejercicio. No deben ser administrardo a mujeres en edad reproductiva debido a los posibles efectos adversos fetales/neonatales.
- Bloqueadores de los canales de calcio o calcioantagonistas: son la mejor opción alternativa a los IECA y ARAII. Pueden provocar palpitacionesn, hinchazón de tobillos, cefaléas y mareos, pero no afectan la capacidad de realizar ejercicio.
- Betabloqueantes: pueden provocar insomnio, frialdad de manos y pies, asma y depresión. Estos fármacos afectan la capacidad de realizar ejercicio, puesto que reducen la frecuencia cardiaca y diminuyen la tolerancia al esfuerzo aumentando la sensación de fatica.
- Los diuréticos: pueden provocar fatiga, debilidad o calambres musculares, ataques de gota, irritabilidad, depression e incontinencia urineria. Estos fármacos si afecta la capacidad de realizar ejercicio, puesto que aumenta la diuresis y favorece la deshidratación.

Cuando un sujeto con hipertensión arterial comienza un programa de ejercicio físico y está bajo tratamiento antihipertensivo se debe tener en cuenta los posibles efectos del mismo: a) la respuesta hipotensiva post-ejercicio; b) la respuesta hipotensiva por cambios de posición, (hipotension ortostática); c) la respuesta hipotensiva como consecuencia de la temperatura (calor y humedad); y d) la respuesta hipotensiva debido a la práctica de ejercicio físico de manera regular y mantenida en el tiempo; estas situaciones pueden hacer que el sujeto experimente mareos, aturdimiento, inestabilidad, nauseas y sensación de cansancio y/o fatiga (Khalil & Zelster, 2020; Laurent, 2017). Ante cualquier situación de hipotensión con sintomatología el sujeto debe ser derivado a su médico para que revise y ajuste el tratamiento si lo ve necesario. Se debe prestar especial atención a los sujetos tratados con betabloqueantes, dado que este fármaco disminuye la frecuencia cardiaca en el esfuerzo y si se atenúa demasiado también podría ocasionar mareos, inestabilidad y sensación de cansancio Y/o fatiga (Khalil & Zelster, 2020; Laurent, 2017; Mitchell et al., 2019). De todos los fármacos antihipertensivos, los betabloqueantes son los que más pueden afectar a la capacidad física para realizar ejercicio, ya que al disminuir el ritmo cardiaco durante la práctica será difícil controlar y ajustar correctamente la carga o estímulo de entrenamiento y conseguir la frecuencia cardiaca deseada, esto implica tener que buscar otra herramienta o método alternativo para controlar dicha variable (Adami et al., 2022; Mitchell et al., 2019). El control de la intensidad del ejercicio a través de la escala de esfuerzo percivido puede ser un método fiable y comúnmente utilido en los programas de rehabilitación cardica como complemento al monitoreo de la frecuencia cardiaca (Mitchell et al., 2019; Taylor et al., 2019). En relación esto, es importante entender que las ecuaciones para estimar la frecuencia cardiaca máxima (FCmáx), como la fórmula de Fox (FCmax = 220 - edad) o la fórmula de Karvonen (FCmax = 208 - (0.7 * edad), estan basadas en sujetos sanos que no padecen hipertensión arterial, insuficiencia cardiaca o enfermedad coronaria y que no están en terapia con betabloquenates, con lo cual, este tipo de ecuaciones no parecen ser muy validas para este tipo de población. Sin embargo, existen fórmulas para estimar la FCmáx que consideran la enfermedad cardiovascular tratada con betabloqueantes. Por ello, se propone la siguiente fórmula para la población que presenta este tipo de afección: 164 – 0.7 x edad, siendo una ecuación más precisa en este grupo de población (Brawner et al., 2004; Fernandes Silva et al., 2012; Taylor et al., 2019).

Adaptación Aguda de la Presión Arterial al Ejercicio Físico

La práctica de ejercicio físico induce una serie de respuestas fisiológicas en el organismo y entre ellas se encuentran los cambios en la dinámica de la presión arterial.

Al inicar la práctica de ejercicio físico se produce un aumento de la presión arterial como respuesta de la activación de la corteza motora cuyo objetivo es preparar al organismo. A continuación, los valores de la presión arterial pueden disminuir debido a la vasodilatación de las zonas activas, dependiendo del tamaño del área de las zonas implicadas. A medida que aumenta la intensidad del entrenamiento la presión arterial sistólica, generalmente, aumenta de manera lineal, por el contrario, la presión arterial diastólica aumenta menos, se mantiene relativamente estable o incluso experimenta una ligera bajada. Al terminar la práctica de ejercicio físico, se recupera paulatinamente los niveles de presión arterial en reposo, pudiendo tardar un tiempo en volver a los niveles previos al entrenamiento. Si la vuelta a la calma no se realiza de manera gradual, puede producirse una hipotensión post-ejercicio, principalmente en sujetos susceptibles o en condiciones climáticas desfavorables, provocando malestar, vertido o lipotimias (Halliwill, 2001; Halliwill et al., 2013; Seeley et al., 2021).

Estas oscilaciones transitorias de la presión arterial durante el ejercicio hacen que sea fundamental su monitorización y control antes, durante y después de la práctica para evitar algún evento cardiaco fatal e inesperado. Las variaciones extremas de estas respuestas pueden ser un valor pronostico significativo de posibles eventos adversos cardiovasculares (Nayor et al., 2023; Pesova et al., 2023). Un aspecto importante a destacar sobre estos cambios extremos es la falta de consenso sobre la definición de respuesta hipertensiva al ejercicio, pese a ello, valores de presión arterial sistólica por encima o

igual a 210 mmHg para los hombres y 190 mmHg para las mujeres son los puntos de corte utilizados a nivel mundial para detener la práctica deportiva y considerar que existe una respuesta hipertensiva al ejercicio (Fletcher et al., 2013; Sabbahi et al., 2018).

Entrenamiento de Resistencia Aeróbica Individualizado en Hipertensión Arterial

- La frecuencia es una variable que hace referencia al número de sesiones o unidades de entrenamiento realizadas en un periodo de tiempo, en el ámbito de la salud, normalmente, sería en la semana (Elvar & García-Orea, 2019). La frecuencia de entrenamiento mínima para este grupo de población será de 2-3 días por semana.
- La duración de la sesión será ≤ 60 minutos.
- La intensidad de entrenamiento prioritaria para mejorar la salud cardiometabólica será moderada, estará entre el 55%-70% del VO^2máx o FCresv, lo que conoce como Zona 2 de entrenamiento (Gu et al., 2021; Riddell et al., 2017; San-Millán, 2023). Para programar la intensidad del entrenamiento de forma individualizada se recomienda estimar el volumen máximo de oxígeno (VO^2máx), la FCmáx, la frecuencia cardiaca de reserva (FCresv) o la percepción de esfuerzo subjetivo (RPE); siendo de preferencia el uso del VO^2máx o la FCresv por su relación lineal 1/1 con el gasto energético (VO^2máx/ VO^2 de reserva) (Ferguson, 2014; Liguori & American College of Sports Medicine, 2020; Manonelles et al., 2016). El cálculo de estos parámetros puede valorarse de manera directa o indirecta. Uno de los protocolos más indicados para estimar del VO^2máx en población hipertensa es por medio de una prueba de esfuerzo en cicloergómetro, por ser más preciso y fácil para medir la presión arterial durante el esfuerzo (Manonelles et al., 2016). Durante la prueba se debe monitorizar y registrar en todo momento la frecuencia cardiaca para conocer la FCmáx; simultáneamente se debe registrar la RPE (Borg, 1990); y además, se debe medir la potencia para conocer el umbral de potencia funcional (FTP), que ofrece una forma precisa y objetiva de medir la intensidad del entrenamiento (Allen et al., 2019). Como se ha comentado anteriormente, la FCmáx también se puede estimar a través de diferentes fórmulas. La más utilizada en el ámbito de la salud son las ya comentadas fórmulas de Fox (Fox et al., 1971; Liguori & American College of Sports Medicine, 2020) o fórmula de Tanaka (Tanaka et al., 2001), pero el valor resultante no es preciso si no meramente orientativo, y para población sin patología. Se propone el uso de la siguiente fórmula para el cálculo de la FCmáx en población con patología cardiaca (FCmáx = 64 – 0.7 x edad) (Brawner et al., 2004; Fernandes Silva et al., 2012; Taylor et al., 2019). Por otro lado, la FCresv y su utilización para el calculo de la intensidad de entrenamiento será más preciso que el uso de la FCmáx y para su cálculo será necesario conocer la frecuencia cardiaca basal o reposo (FCbasal). La FCresv se calculará por medio de la fórmula de Karvonen: FCresv = FCmáx - FCbasal. Una vez conocido estos datos se calculará el porcentaje prescrito de intensidad. Para ello se utilizará la fórmula de Karvonen (% de FC= (FCresv × % de intensidad) + FCbasal) (Karvonen et al., 1957).
- En relación con la escala RPE (Rating of Perceived Exertion), definida como la percepción subjetiva del esfuerzo, tensión y/o fatiga experimentada durante la práctica de ejercicio físico, es un indicador de intensidad fiable y comúnmente utilizado en los programas de rehabilitación cardiaca simultáneamente con el monitoreo de la frecuencia cardiaca (Mitchell et al., 2019; Taylor et al., 2019). Esta escala valora numéricamente y de forma gradual del 0 al 10, donde 0 es reposo total y 10 esfuerzo máximo (Borg, 1982).
- Las zonas e intensidades de entrenamiento, desde ergometrías máximas, quedan reflejadas en la tabla 1 (Hansen et al., 2021; Pelliccia et al., 2020).

Tabla 1
Zonas e Intensidades de Entrenamiento de Resistencia

Zona	Intensidad	VO^2máx (%)	FCmáx (%)	FCresv (%)
1	Baja	< 40	< 55	< 40
2	Moderada	40-69	55-74	40-69
3-4	Alta	70-85	75-90	70-85
5	Muy Alta	> 85	> 90	> 85

Nota. Esta tabla muestra la equivalencia de las zonas de entrenamiento con la intensidad de entrenamiento, el volumen máximo de oxígeno (VO^2máx), la frecuencia cardiaca máxima (FCmáx) y la frecuencia cardiaca de reserva (FCresv) (Pelliccia et al., 2020).

- El volumen de entrenamiento mínimo para este tipo de población será de 150 a 300 minutos/semana (5-7 días/semana) si el ejercicio se realiza con intensidad moderada (zona 2). Se puede alternar de 75 a 150 minutos/semana (2-3 días/semana) si la intensidad es vigorosa (zona 3) (Bull et al., 2020; McEvoy et al., 2024).
- El tipo de actividad a realizar debe implicar grandes grupos musculares, movimientos cíclicos y mantenidos durante un medio-largo periodo de tiempo como pedalear, correr, remar, nadar etc.

Entrenamiento de Fuerza Individualizado en Hipertensión Arterial

- La frecuencia mínima de entrenamiento para este grupo de población será de 2-3 días por semana no consecutivos.
- La duración de la sesión ≤ 60 minutos.
- Incluir ejercicios poliarticulares que impliquen grandes grupos musculares que simulen actividades de la vida diaria (sentadillas, remos, press banca, etc).
- El número de ejercicios por sesión se deben progresar de seis hasta 8-10 ejercicios (López-Ruiz et al., 2023; Pescatello, 2020; Whelton et al., 2018).
- La intensidad en el entrenamiento de fuerza será la variable más determinante para configurar el grado de esfuerzo que exige la ejecución de un ejercicio en cada repetición, que debe ser bajo-moderado para este grupo de población (Badillo & Serna, 2002; Elvar & García-Orea, 2019). La cuantificación de la carga de entrenamiento se hará a través de la velocidad de ejecución mediante un test de cargas progresivas para estimar la 1RM, de manera segura y precisa, y determinar la intensidad relativa de trabajo, pero la intensidad, por si sola, no es suficiente para definir el estímulo de entrenamiento y debe ir unida especialmente a otra de las variables de la programación, a el volumen (Badillo, 2017; Badillo & Serna, 2002).
- El volumen se debe concretar mediante un test de porcentaje de la perdida de velocidad intra-serie con respecto a la 1ª repetición. La magnitud de perdida de velocidad debe ser baja-moderada, entre un 10%-20%, ya que porcentajes más altos de perdida de velocidad no se asocian con mayores beneficios y pueden suponer una reducción del rendimiento físico (Badillo & Serna, 2002; Rodríguez-Rosell et al., 2020; Rodríguez-Rosell et al., 2021).
- A continuación, se realiza una propuesta de protocolo para prescribir la intensidad en sujetos con hipertensión arterial. La intensidad se determinará a través de un test de cargas progresivas para estimar la 1RM y establecer una intensidad baja-moderada de trabajo, entre el 50-65% de 1RM para este tipo de población (Alves et al., 2022; Pescatello, 2020). Las recomendaciones actuales de intensidad de trabajo en el entrenamiento de fuerza en hipertensión, según el Colegio Americano de Medicina del Deporte (ACSM), son las siguientes: intensidad baja, entre el 40%-50% de 1RM, para sujetos sedentarios o con debilidad muscular; intensidad moderada, entre el 60%-70% de 1RM, para sujetos principiantes o intermedios; intensidad alta, un 80% de 1RM, para sujetos avanzados y experimentados en el entrenamiento (Alves et al., 2022; Pescatello, 2020; Pescatello et al., 2015).El volumen de entrenamiento, o número de repeticiones por serie, se concretará a través de un test de perdida de velocidad intraserie para cada sujeto. La magnitud de perdida de velocidad (%PV) debe ser baja-moderada, entre un 10-15% (Badillo, 2017; Rodríguez-Rosell et al., 2020; Sánchez-Medina & González-Badillo, 2011).
- El carácter de esfuerzo (CE) debe ser medio-bajo. Se entiende por CE la relación entre las repeticiones realizadas en cada serie con respecto a las repeticiones que se podrían realizar si se llegara al fallo muscular (Badillo & Serna, 2002), como se puede ver en la tabla 2. No confundir el CE con la percepción subjetiva de esfuerzo.

Tabla 2
Caracter de Esfuerzo

CE	%PV en la serie	Repeticiones realizadas en la serie
Bajo	5-10%	Menos de la mitad de las posibles
Medio	15-30%	La mitad de las posibles
Alto	>30%	Alguna más de la mitad de las posibles
Máximo	>50%	Máximo o casi máximo número de las posibles

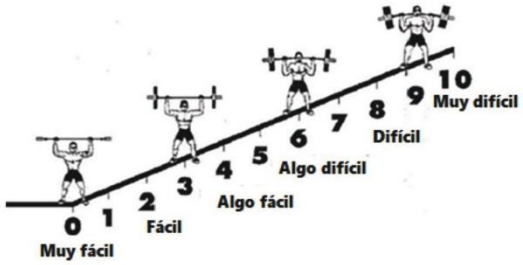
Nota. Esta tabla muestra la relación entre el caráter de esfuerzo (CE), el porcentaje de perdida de velocidad (%PV) intra-serie respecto a la 1ª repetición y las repeticiones realizadas por serie con respecto a las máximas que realmente se podrían realizer (Badillo & Serna, 2002).

- El número de series por ejercicio pueden ser de 2-4, según el punto de partida y la evolución del sujeto.
- El tiempo de recuperación entre series de entrenamiento será de 3-5 minutos
- El tiempo de recuperación entre sesiones de entrenamiento será de 48-72 horas.

Respecto a la programación del entrenamieto, aunque cada vez se dispone de más recursos y dispositivos tecnológicos, que sin duda han permitido programar de forma más precisa la intensidad y el volumen del entrenamiento y conseguido evolucionar en la dosificación del esfuerzo, no se debe menospreciar otras herramientas o indicadores más simples y que son fácilmente accesibles para este mismo fin. Una de estas herramientas es la escala OMNI-RES, la cual se presenta como descriptores visuales donde el sujeto identifica su propia percepción de esfuerzo o fatiga sobre una escala numéricamente

gradual del 0 al 10, como se muestra en la figura 1, donde 0 es muy fácil y el 10 es muy difícil, durante o inmediatamente después del ejercicio (Robertson et al., 2003).

Figura 1
Escala OMNI-RES para fuerza



Nota. Esta escala representa la propia percepción de esfuerzo o fatiga del sujeto sobre una progresión numéricamente del 0 (muy fácil) al 10 (muy difícil) (Robertson et al., 2003).

Entrenamiento Combinado Individualizado en Hipertensión Arterial

El ensayo clínico Corazón y Salud se centra en los programas de entrenamiento combinado, entendido este como aquel que en la misma sesión de entrenamiento combina unidades de entrenamiento diferentes, el trabajo de fuerza y el de resistencia aeróbica. El entrenamiento combinado ha mostrado ser eficaz en la reducción de los niveles de presión arterial y en la mejora de la salud cardiometabólica en sujetos con hipertensión arterial (Herrod et al., 2018; López-Ruiz et al., 2023). Diferentes ensayos controlados han mostrado reducciones significativas en los niveles de PAS y PAD con intervenciones de programas de entrenamiento combinado (Dos Santos et al., 2014; Lima et al., 2017; Masroor et al., 2018; Sousa et al., 2013). Además, se pueden encontrar revisiones sistemáticas y metaanálisis cuyos resultados también han mostrado que intervenciones con entrenamiento combinado consiguieron reducir significativamente los niveles de PAS y PAD (Corso et al., 2016; López-Ruiz et al., 2023; Pescatello et al., 2019).

La intención del presente proyecto es servir de guía a los profesionales de la salud para poder diseñar los programas de entrenamiento combinado de manera individualizada para cada sujeto con una dosis mínima, pero efectiva, de ejercicio. Estas intervenciones van dirigidas a sujetos adultos con hipertensión arterial, sedentarios, que no sufran problemas osteoarticulares o musculoesqueléticos (osteoartritis, fractura reciente, tendinitis o uso de prótesis), enfermedad aguda o crónica (cardiopatías, enfermedad coronaria inestable, insuficiencia cardíaca, insuficiencia renal, hipertensión pulmonar grave o diabetes no controlada), problemas neurológicos, dificultades cognitivas, obesidad mórbida o embarazadas.

Programa de Entrenamiento Combinado Corazón y Salud

A continuación, se muestra un diseño de programa de entrenamiento combinado individualizado de fuerza y resistencia aeróbica teniendo en cuenta las pautas de ejercicio descritas anteriormente para sujetos adultos con hipertensión arterial. Esta prescripción de ejercicio ha mostrado grandes beneficios para la salud cardiometabólica, la composición corporal y la condición física en este tipo de población.

Cada sesión de entrenamiento tendrá una duración de 60 min aproximadamente y estará dividida en tres fases que se pueden ver de forma resumida en la tabla 3.

Fase Preparatoria al Entrenamiento

Esta primera fase tiene una duración de unos 10 min y estará dividida en un calentamiento general y un calentamiento específico. El calentamiento general incluirá 5 min de marcha nórdica en bicicleta elíptica; ejercicios de movilidad articular de miembros superiores e inferiores y estiramientos dinámicos. El calentamiento específico incluirá dos ejercicios globales, un squat y un press banca; el sujeto realizará dos series por ejercicio solamente con el peso de la barra de entrenamiento (5 kg de peso) y descansará 2 min entre series; la primera serie de 8-10 repeticiones y la segunda serie de 6-8 repeticiones.

Tabla 3
Programa de Entrenamiento Combinado Corazón y Salud

Periodo de intervención		12 Semanas
Frecuencia semanal		2 sesiones/semana; 4 unidades de entrenamiento/semana (2 de fuerza; 2 de resistencia)
Unidad de Entrenamiento de Fuerza		
Calentamiento		10 min (3-5 min calentamiento general y 5-7 min calentamiento específico)
Volumen	Nº Ejercicios	2 ejercicios generales (sentadilla y press de banca)
	Nº de Series	3
	Nº Repeticiones	Individualizadas para cada paciente mediante %PV intra-serie
Intensidad	% Pérdida de velocidad (intra-serie)	Sentadillas: Baja 10% Press de banca: Moderada 15%
	% 1RM VMP 1ª Repetición	Sentadillas: 60% de 1RM Press de banca: 50% de 1RM
	Velocidad de Ejecución	Fase concéntrica: máxima posible Fase excéntrica: moderada
Carácter de esfuerzo		Medio-Bajo
OMNI-RES		4-5
Descanso inter-serie		3 min
Selección de Ejercicios		Sentadilla - Press Banca
Método		Progresión Horizontal
Unidad de Entrenamiento de Resistencia Aeróbica		
Volumen		20 min
Intensidad		Progresar cada cuatro semanas del 55% al 70% del VO^2máx/ FCresv
Zona de Entrenamiento		2
RPE del 0 al 10		Moderada 3-4
Selección de Ejercicios		Cicloergómetro
Método		Entrenamiento continuo extensivo
Vuelta a la calma		10 min (3-5 min vuelta a la calma y 5-7 min estiramientos estáticos pasivos)

Nota. Nº= número; RM= repetición máxima; VO^2máx= volumen máximo de oxígeno; FCresv= frecuencia cardiaca de reserva; VMP= velocidad media propulsiva; OMNI-RES= escala de esfuerzo percibido para ejercicios de resistencia; RPE= escala de esfuerzo percibido.

Fase Principal

La segunda fase presenta una una duración de 40 min y estará compuesta por dos unidades de entrenamiento, una de fuerza y otra de resistencia aeróbica. La unidad de entrenamiento de fuerza se realizará durante los primeros 20 min de la sesion y en ella se incluirán dos ejercicios que reproducen acciones motrices básicas. El primer ejercicio será un empuje de hemisferio inferior del cuerpo, un squat, que cada sujeto realizará a una intensidad del 60% de su 1RM. El volumen de trabajo será de tres series con un descanso entre cada una de ellas de 3 min. El número de repeticiones por serie será individualizado para cada sujeto mediante el test inicial de perdida de velocidad. El carácter de esfuerzo será bajo-medio. Entre los dos ejercicios también habrá un descanso de 3 min. El segundo ejercicio será un empuje de hemisferio superior del cuerpo, un press banca, que cada sujeto realizará a una intensidad del 50% de su 1RM. El volumen de trabajo será de tres series con un descanso entre cada una de ellas de 3 min. El número de repeticiones por serie será individualizado para cada sujeto mediante el test inicial de perdida de velocidad. El carácter de esfuerzo será bajo-medio. Como se ha explicado anteriormente, si no se dispone de las herramientas necesarias para poder estimar la 1RM se puede utilizar la escala OMNI-RES. Los últimos 20 min de la sesión serán para la unidad de entrenamiento de resistencia aeróbica que se realizán en cicloergómetro. El sujeto trabajará con un método continuo extensivo a una intensidad moderada que irá progresando cada 4 semanas: de la semana 1 a la 4 trabajo en zona 1-2 con una intensidad entre el 55%-60% FCresv; de la semana 5 a la 8 trabajo en zona 2 con una intensidad entre el 60%-65% FCresv; y de la semana 9 a la 12 trabajo en zona 2 con una intensidad entre el 65%-70% FCresv.

Fase de Recuperación Post-Entrenamiento

El tiempo dedicado a la última parte del entrenamiento será de 10 min. Esta fase constará de una vuelta a la calma de unos 3-5 min en la que el sujeto irá recuperándose del esfuerzo con un pedaleo suave sin carga para después pasar a una parte de estiramientos estáticos de unos 5-7 min. Se debe estirar la musculatura con predominancia tónica/postural debido a su estado de tensión permanente y su tendencia al acortamiento para evitar posibles problemas musculoesqueléticos que afecten al sistema locomotor (Chang et al., 2023; Sadler et al., 2017). La musculatura tónica incluye: fibras superiores del trapecio, dorsal ancho y cuadrado lumbar; pectoral, deltoides anterior y bíceps; psoas ilíaco y recto anterior del cuadríceps; abductores; piramidal, isquiosurales y tríceps sural (gemelos y sóleo). Se recomienda utilizar la técnica estático pasiva, realizando 3-4 series por estiramiento y la duración por serie será de 20-30 segundos (Bayles, 2023; Liguori & American College of Sports Medicine, 2020).

Conclusiones

El programa de entrenamiento combinado diseñado en el proyecto Corazón y Salud proporciona una guía a los profesionales del ejercicio y la salud basada en la evidencia científica y en los últimos avances sobre prescripción de ejercicio físico en población con hipertensión arterial; una de las enfermedades no transmisibles más prevalentes de la sociedad actual y responsable de 10.8 millones de muertes al año en el mundo. En este estudio se marcan las pautas a seguir para diseñar un correcto, adecuado y seguro programa de entrenamiento combinado para conseguir los beneficios que proporcionan ambas modalidades de ejercicio, tanto el entrenamiento de fuerza como el de resistencia aeróbica, con el objetivo de mejorar los parámetros hemodinámicos, la composición corporal y la condición física de los sujetos adultos con hipertensión arterial.

Declaración del Comité de Ética

No aplica debido a la no implicación de seres vivos durante el desarrollo del presente artículo.

Conflicto de Intereses

Los autores declaran no tener ningún conflicto de interés

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Contribución de los Autores

Conceptualización L.-R.I. & G.G.N.; Metodología L.-R.I. & G.G.N.; Validación L.-R.I., L.G., M.M.D., & G.G.N.; Investigación L.-R.I. & G.G.N.; Escritura – version original L.-R.I. & G.G.N.; Escritura – revision y edición L.-R.I. & G.G.N.; Visualización L.-R.I., L.G., M.M.D., & G.G.N.; Supervisión G.G.N.; Todos los autores han leído y están de acuerdo con la versión publicada del manuscrito.

Declaración de Disponibilidad de Datos

Los datos no se encuentran disponibles debido a que no se han generado datos.

Referencias

Adami, P. E., Koutlianos, N., Baggish, A., Bermon, S., Cavarretta, E., Deligiannis, A., Furlanello, F., Kouidi, E., Marques-Vidal, P., Niebauer, J., Pelliccia, A., Sharma, S., Solberg, E. E., Stuart, M., & Papadakis, M. (2022). Cardiovascular effects of doping substances, commonly prescribed medications and ergogenic aids in relation to sports: a position statement of the sport cardiology and exercise nucleus of the European Association of Preventive Cardiology. *European Journal of Preventive Cardiology*, *29*(3), 559-575. https://doi.org/10.1093/eurjpc/zwab198

Allen, H., Coggan, A. R., & McGregor, S. (2019). *Training and racing with a power meter*. VeloPress.

Alves, A. J., Wu, Y., Lopes, S., Ribeiro, F., & Pescatello, L. S. (2022). Exercise to Treat Hypertension: Late Breaking News on Exercise Prescriptions That FITT. *Current Sports Medicine Reports*, *21*(8), 280-288. https://doi.org/10.1249/jsr.0000000000000983

Arnett, D. K., Blumenthal, R. S., Albert, M. A., Buroker, A. B., Goldberger, Z. D., Hahn, E. J., Himmelfarb, C. D., Khera, A., Lloyd-Jones, D., McEvoy, J. W., Michos, E. D., Miedema, M. D., Muñoz, D., Smith, S. C., Jr, Virani, S. S., Williams, K. A., Sr, Yeboah, J., & Ziaeian, B. (2019). 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report

of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*, *140*(11), e596-e646. https://doi.org/10.1161/cir.0000000000000678

Badillo, J. J. G. (2017). *La velocidad de ejecución como referencia para la programación, control y evaluación del entrenamiento de fuerza*. Ergotech.

Badillo, J. J. G., & Serna, J. R. (2002). *Bases de la programación del entrenamiento de fuerza*. Inde.

Bayles, M. P. (2023). *ACSM's exercise testing and prescription*. Lippincott Williams & Wilkins.

Bishop, D. (2003a). Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports Medicine*, *33*(6), 439-454. https://doi.org/10.2165/00007256-200333060-00005

Bishop, D. (2003b). Warm up II: performance changes following active warm up and how to structure the warm up. *Sports Medicine*, *33*(7), 483-498. https://doi.org/10.2165/00007256-200333070-00002

Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scandinavian Journal of Work, Environment & Health, 16*(1), 55-58. https://doi.org/10.5271/sjweh.1815

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, *14*(5), 377-381.

Brawner, C. A., Ehrman, J. K., Schairer, J. R., Cao, J. J., & Keteyian, S. J. (2004). Predicting maximum heart rate among patients with coronary heart disease receiving beta-adrenergic blockade therapy. *American Heart Journal*, *148*(5), 910-914. https://doi.org/10.1016/j.ahj.2004.04.035

Brook, R. D., Appel, L. J., Rubenfire, M., Ogedegbe, G., Bisognano, J. D., Elliott, W. J., Fuchs, F. D., Hughes, J. W., Lackland, D. T., Staffileno, B. A., Townsend, R. R., & Rajagopalan, S. (2013). Beyond medications and diet: alternative approaches to lowering blood pressure: a scientific statement from the american heart association. *Hypertension*, *61*(6), 1360-1383. https://doi.org/10.1161/HYP.0b013e318293645f

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., ... Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451-1462. https://doi.org/10.1136/bjsports-2020-102955

Chang, M. C., Choo, Y. J., Hong, K., Boudier-Revéret, M., & Yang, S. (2023). Treatment of Upper Crossed Syndrome: A Narrative Systematic Review. *Healthcare (Basel)*, *11*(16). https://doi.org/10.3390/healthcare11162328

Charchar, F. J., Prestes, P. R., Mills, C., Ching, S. M., Neupane, D., Marques, F. Z., Sharman, J. E., Vogt, L., Burrell, L. M., Korostovtseva, L., Zec, M., Patil, M., Schultz, M. G., Wallen, M. P., Renna, N. F., Islam, S. M. S., Hiremath, S., Gyeltshen, T., Chia, Y.-C., ... Tomaszewski, M. (2024). Lifestyle management of hypertension: International Society of Hypertension position paper endorsed by the World Hypertension League and European Society of Hypertension. *Journal of Hypertension*, *42*(1), 23-49. https://doi.org/10.1097/hjh.0000000000003563

Corso, L. M. L., Macdonald, H. V., Johnson, B. T., Farinatti, P., Livingston, J., Zaleski, A. L., Blanchard, A., & Pescatello, L. S. (2016). Is Concurrent Training Efficacious Antihypertensive Therapy? A Meta-analysis. *Medicine and Science in Sports and Exercise*, *48*(12), 2398-2406. https://doi.org/10.1249/mss.0000000000001056

Dos Santos, E. S., Asano, R. Y., Filho, I. G., Lopes, N. L., Panelli, P., Nascimento, D. da C., Collier, S. R., & Prestes, J. (2014). Acute and chronic cardiovascular response to 16 weeks of combined eccentric or traditional resistance and aerobic training in elderly hypertensive women: a randomized controlled trial. *Journal of Strength and Conditioning Research*, *28*(11), 3073-3084. https://doi.org/10.1519/jsc.0000000000000537

Elvar, J. R. H., & García-Orea, G. P. (2019). *El entrenamiento de la fuerza para la mejora de la condición física y la salud*. Círculo rojo.

Ferguson, B. (2014). ACSM's Guidelines for Exercise Testing and Prescription 9th Ed. 2014. *Journal of the Canadian Chiropractic Association, 58*(3), 328-329.

Fernandes Silva, M. M., Bacal, F., Roque, J. M., Teixeira-Neto, I. S., Carvas Junior, N., Bocchi, E. A., & Guimarães, G. V. (2012). Age-related maximum heart rate among ischemic and nonischemic heart failure patients receiving β-blockade therapy. *Journal of Cardiac Failure*, *18*(11), 831-836. https://doi.org/10.1016/j.cardfail.2012.10.007

Fleck, S. J., & Kraemer, W. (2014). *Designing resistance training programs, 4E*. Human Kinetics.

Fletcher, G. F., Ades, P. A., Kligfield, P., Arena, R., Balady, G. J., Bittner, V. A., Coke, L. A., Fleg, J. L., Forman, D. E., Gerber, T. C., Gulati, M., Madan, K., Rhodes, J., Thompson, P. D., & Williams, M. A. (2013). Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation*, *128*(8), 873-934. https://doi.org/10.1161/CIR.0b013e31829b5b44

Fox, S. M., 3rd, Naughton, J. P., & Haskell, W. L. (1971). Physical activity and the prevention of coronary heart disease. *Annals of Clinical Research*, *3*(6), 404-432.

Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects of warming-up on physical performance: a systematic review with meta-analysis. *Journal of Strength and Conditioning Research*, *24*(1), 140-148. https://doi.org/10.1519/JSC.0b013e3181c643a0

Gorostidi, M., Gijón-Conde, T., de la Sierra, A., Rodilla, E., Rubio, E., Vinyoles, E., Oliveras, A., Santamaría, R., Segura, J., Molinero, A., Pérez-Manchón, D., Abad, M., Abellán, J., Armario, P., Banegas, J. R., Camafort, M., Catalina, C., Coca, A., Divisón, J. A., ... García-Donaire, J. A. (2022). Guía práctica sobre el diagnóstico y tratamiento de la hipertensión arterial en España, 2022. Sociedad Española de Hipertensión-Liga Española para la Lucha contra la Hipertensión Arterial (SEH-LELHA). *Hipertensión y Riesgo Vascular*, *39*(4), 174-194. https://doi.org/10.1016/j.hipert.2022.09.002

Gu, C., Yan, J., Zhao, L., Wu, G., & Wang, Y. L. (2021). Regulation of Mitochondrial Dynamics by Aerobic Exercise in Cardiovascular Diseases. *Frontiers in Cardiovascular Medicine*, *8*, 788505. https://doi.org/10.3389/fcvm.2021.788505

Halliwill, J. R. (2001). Mechanisms and clinical implications of post-exercise hypotension in humans. *Exercise and Sport Sciences Reviews*, *29*(2), 65-70. https://doi.org/10.1097/00003677-200104000-00005

Halliwill, J. R., Buck, T. M., Lacewell, A. N., & Romero, S. A. (2013). Postexercise hypotension and sustained postexercise vasodilatation: what happens after we exercise? *Experimental Physiology*, *98*(1), 7-18. https://doi.org/10.1113/expphysiol.2011.058065

Hansen, D., Abreu, A., Ambrosetti, M., Cornelissen, V., Gevaert, A., Kemps, H., Laukkanen, J. A., Pedretti, R., Simonenko, M., Wilhelm, M., Davos, C. H., Doehner, W., Iliou, M.-C., Kränkel, N., Völler, H., & Piepoli, M. (2021). Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology. *European Journal of Preventive Cardiology*, *29*(1), 230-245. https://doi.org/10.1093/eurjpc/zwab007

Hanssen, H., Boardman, H., Deiseroth, A., Moholdt, T., Simonenko, M., Kränkel, N., Niebauer, J., Tiberi, M., Abreu, A., Solberg, E. E., Pescatello, L., Brguljan, J., Coca, A., & Leeson, P. (2021). Personalized exercise prescription in the prevention and treatment of arterial hypertension: a Consensus Document from the European Association of Preventive Cardiology (EAPC) and the ESC Council on Hypertension. *European Journal of Preventive Cardiology, 29*(1), 205–215. https://doi.org/10.1093/eurjpc/zwaa141

Herrod, P. J. J., Doleman, B., Blackwell, J. E. M., O'Boyle, F., Williams, J. P., Lund, J. N., & Phillips, B. E. (2018). Exercise and other nonpharmacological strategies to reduce blood pressure in older adults: a systematic review and meta-analysis. *Journal of the American Society of Hypertension: JASH*, *12*(4), 248-267. https://doi.org/10.1016/j.jash.2018.01.008

Karvonen, M. J., Kentala, E., & Mustala, O. (1957). The effects of training on heart rate; a longitudinal study. *Annales Medicinae Experimentalis et Biologiae Fenniae*, *35*(3), 307-315.

Khalil, H., & Zelster, R. (8 de mayo de 2023). *Antihypertensive Medications.* NCBI. https://www.ncbi.nlm.nih.gov/books/NBK554579/

Laurent, S. (2017). Antihypertensive drugs. *Pharmacological Research: The Official Journal of the Italian Pharmacological Society*, *124*, 116-125. https://doi.org/10.1016/j.phrs.2017.07.026

Liguori, G., & American College of Sports Medicine (2020). *ACSM's guidelines for exercise testing and prescription*. Lippincott Williams & Wilkins.

Lima, L. G., Bonardi, J. T. M., Campos, G. O., Bertani, R. F., Scher, L. M. L., Moriguti, J. C., Ferriolli, E., & Lima, N. K. C. (2017). Combined aerobic and resistance training: are there additional benefits for older hypertensive adults? *Clinics (Sao Paulo)*, *72*(6), 363-369. https://doi.org/10.6061/clinics/2017(06)06

Liu, X., Zhang, D., Liu, Y., Sun, X., Han, C., Wang, B., Ren, Y., Zhou, J., Zhao, Y., Shi, Y., Hu, D., & Zhang, M. (2017). Dose-Response Association Between Physical Activity and Incident Hypertension: A Systematic Review and Meta-Analysis of Cohort Studies. *Hypertension*, *69*(5), 813-820. https://doi.org/10.1161/hypertensionaha.116.08994

López-Ruiz, I., Lozano, F., Masia, M. D., & González-Gálvez, N. (2023). Multicomponent Training and Optimal Dosing Strategies for Adults with Hypertension: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Sports (Basel)*, *11*(6). https://doi.org/10.3390/sports11060115

Mancia, G., Kreutz, R., Brunström, M., Burnier, M., Grassi, G., Januszewicz, A., Muiesan, M. L., Tsioufis, K., Agabiti-Rosei, E., Algharably, E. A. E., Azizi, M., Benetos, A., Borghi, C., Hitij, J. B., Cifkova, R., Coca, A., Cornelissen, V., Cruickshank, J. K., Cunha, P. G., ... Kjeldsen, S. E. (2023). 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). *Journal of Hypertension*, *41*(12), 1874-2071. https://doi.org/10.1097/hjh.0000000000003480

Marcos-Pardo, P., González-Gálvez, N., Vaquero-Cristóbal, R., Sagarra, L., López-Vivancos, A., Velazquez, D., Gea-García, G.M., Ponce-González, J.G., Esteban-Cornejo, I., Jiménez-Pavón, D., & Carbonell-Baeza, A. (2021). Programa de Intervención

Multidominio Healthy-Age. Recomendaciones para un envejecimiento saludable: por la red Healthy-Age. *Cultura, Ciencia y Deporte*, *16*, 311-320. https://doi.org/10.12800/ccd.v16i48.1743

Manonelles, P., Franco, L., & Naranjo, J. (2016). Pruebas de esfuerzo en medicina del deporte. Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE). *Archivos de medicina del deporte*, *33*(1), 5-83. https://www.femede.es/documentos/Consenso_PE.pdf

Masroor, S., Bhati, P., Verma, S., Khan, M., & Hussain, M. E. (2018). Heart Rate Variability following Combined Aerobic and Resistance Training in Sedentary Hypertensive Women: A Randomised Control Trial. *Indian Heart Journal*, *70*(3), 28-35. https://doi.org/10.1016/j.ihj.2018.03.005

McEvoy, J. W., McCarthy, C. P., Bruno, R. M., Brouwers, S., Canavan, M. D., Ceconi, C., Christodorescu, R. M., Daskalopoulou, S. S., Ferro, C. J., Gerdts, E., Hanssen, H., Harris, J., Lauder, L., McManus, R. J., Molloy, G. J., Rahimi, K., Regitz-Zagrosek, V., Rossi, G. P., Sandset, E. C., … ESC Scientific Document Group (2024). 2024 ESC Guidelines for the management of elevated blood pressure and hypertension. *European Heart Journal*, *45*(38), 3912-4018. https://doi.org/10.1093/eurheartj/ehae178

McGowan, C. J., Pyne, D. B., Thompson, K. G., & Rattray, B. (2015). Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. *Sports Medicine*, *45*(11), 1523-1546. https://doi.org/10.1007/s40279-015-0376-x

Mensah, G. A., Fuster, V., Murray, C. J. L., & Roth, G. A. (2023). Global Burden of Cardiovascular Diseases and Risks, 1990-2022. *Journal of the American College of Cardiology*, *82*(25), 2350-2473. https://doi.org/10.1016/j.jacc.2023.11.007

Menéndez, E., Delgado, E., Fernández-Vega, F., Prieto, M. A., Bordiú, E., Calle, A., Carmena, R., Castaño, L., Catalá, M., Franch, J., Gaztambide, S., Girbés, J., Goday, A., Gomis, R., López-Alba, A., Martínez-Larrad, M. T., Mora-Peces, I., Ortega, E., Rojo-Martínez, G., … Soriguer, F. (2016). Prevalence, Diagnosis, Treatment, and Control of Hypertension in Spain. Results of the Di@bet.es Study. *Revista Espanola de Cardiologia*, *69*(6), 572-578. https://doi.org/10.1016/j.rec.2015.11.034

Mitchell, B. L., Davison, K., Parfitt, G., Spedding, S., & Eston, R. G. (2019). Physiological and Perceived Exertion Responses during Exercise: Effect of β-blockade. *Medicine and Science in Sports and Exercise*, *51*(4), 782-791. https://doi.org/10.1249/mss.0000000000001845

Nayor, M., Gajjar, P., Murthy, V. L., Miller, P. E., Velagaleti, R. S., Larson, M. G., Vasan, R. S., Lewis, G. D., Mitchell, G. F., & Shah, R. V. (2023). Blood Pressure Responses During Exercise: Physiological Correlates and Clinical Implications. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *43*(1), 163-173. https://doi.org/10.1161/atvbaha.122.318512

Nazir, A., Heryaman, H., Juli, C., Ugusman, A., Martha, J. W., Moeliono, M. A., & Atik, N. (2024). Resistance Training in Cardiovascular Diseases: A Review on Its Effectiveness in Controlling Risk Factors. *Integrated Blood Pressure Control*, *17*, 21-37. https://doi.org/10.2147/ibpc.s449086

NICE (2023). *Hypertension in adults: diagnosis and management*. National Institute for Health and Care Excellence. https://www.nice.org.uk/guidance/ng136/resources/hypertension-in-adults-diagnosis-and-management-pdf-66141722710213

OMS (1989). *Diet, Nutrition and the Prevention of Chronic Diseases*. World Health Organization. https://iris.who.int/bitstream/handle/10665/42665/WHO_TRS_916.pdf

OMS (2023). *Global report on hypertension: The race against a silent killer*. World Health Organization. https://www.who.int/publications/i/item/9789240081062

Pedersen, B. K. (2006). The anti-inflammatory effect of exercise: its role in diabetes and cardiovascular disease control. *Essays Biochem*, *42*, 105-117. https://doi.org/10.1042/bse0420105

Pedersen, B. K., & Saltin, B. (2015). Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases. *Scandinavian Journal of Medicine & Science in Sports*, *25*(3), 1-72. https://doi.org/10.1111/sms.12581

Pelliccia, A., Sharma, S., Gati, S., Bäck, M., Börjesson, M., Caselli, S., Collet, J.-P., Corrado, D., Drezner, J. A., Halle, M., Hansen, D., Heidbuchel, H., Myers, J., Niebauer, J., Papadakis, M., Piepoli, M. F., Prescott, E., Roos-Hesselink, J. W., Graham Stuart, A., … ESC Scientific Document Group. (2020). 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease: The Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). *European Heart Journal*, *42*(1), 17-96. https://doi.org/10.1093/eurheartj/ehaa605

Pescatello, L. S. (11 de junio de 2020). *What's New in the ACSM Pronouncement on Exercise and Hypertension*. American College of Sport Medicine. https://acsm.org/exercise-hypertension/

Pescatello, L. S., Buchner, D. M., Jakicic, J. M., Powell, K. E., Kraus, W. E., Bloodgood, B., Campbell, W. W., Dietz, S., Dipietro, L., George, S. M., Macko, R. F., McTiernan, A., Pate, R. R., & Piercy, K. L. (2019). Physical Activity to Prevent and Treat Hypertension: A Systematic Review. *Medicine and Science in Sports and Exercise*, *51*(6), 1314-1323. https://doi.org/10.1249/mss.0000000000001943

Pescatello, L. S., MacDonald, H. V., Lamberti, L., & Johnson, B. T. (2015). Exercise for Hypertension: A Prescription Update Integrating Existing Recommendations with Emerging Research. *Current Hypertension Reports*, *17*(11), 87. https://doi.org/10.1007/s11906-015-0600-y

Pesova, P., Jiravska Godula, B., Jiravsky, O., Jelinek, L., Sovova, M., Moravcova, K., Ozana, J., Gajdusek, L., Miklik, R., Sknouril, L., Neuwirth, R., & Sovova, E. (2023). Exercise-Induced Blood Pressure Dynamics: Insights from the General Population and the Athletic Cohort. *Journal of Cardiovascular Development and Disease*, *10*(12). https://doi.org/10.3390/jcdd10120480

Rabi, D. M., McBrien, K. A., Sapir-Pichhadze, R., Nakhla, M., Ahmed, S. B., Dumanski, S. M., Butalia, S., Leung, A. A., Harris, K. C., Cloutier, L., Zarnke, K. B., Ruzicka, M., Hiremath, S., Feldman, R. D., Tobe, S. W., Campbell, T. S., Bacon, S. L., Nerenberg, K. A., Dresser, G. K., … Daskalopoulou, S. S. (2020). Hypertension Canada's 2020 Comprehensive Guidelines for the Prevention, Diagnosis, Risk Assessment, and Treatment of Hypertension in Adults and Children. *The Canadian Journal of Cardiology*, *36*(5), 596-624. https://doi.org/10.1016/j.cjca.2020.02.086

Riddell, M. C., Gallen, I. W., Smart, C. E., Taplin, C. E., Adolfsson, P., Lumb, A. N., Kowalski, A., Rabasa-Lhoret, R., McCrimmon, R. J., Hume, C., Annan, F., Fournier, P. A., Graham, C., Bode, B., Galassetti, P., Jones, T. W., Millán, I. S., Heise, T., Peters, A. L., … Laffel, L. M. (2017). Exercise management in type 1 diabetes: a consensus statement. *The Lancet. Diabetes & Endocrinology*, *5*(5), 377-390. https://doi.org/10.1016/s2213-8587(17)30014-1

Rijal, A., Adhikari, T. B., Dhakal, S., Maagaard, M., Piri, R., Nielsen, E. E., Neupane, D., Jakobsen, J. C., & Olsen, M. H. (2024). Effects of adding exercise to usual care on blood pressure in patients with hypertension, type 2 diabetes, or cardiovascular disease: a systematic review with meta-analysis and trial sequential analysis. *Journal of Hypertension*, *42*(1), 10-22. https://doi.org/10.1097/hjh.0000000000003589

Rimoldi, S. F., Scherrer, U., & Messerli, F. H. (2014). Secondary arterial hypertension: when, who, and how to screen? *European Heart Journal*, *35*(19), 1245-1254. https://doi.org/10.1093/eurheartj/eht534

Robertson, R. J., Goss, F. L., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J., Frazee, K., Dube, J., & Andreacci, J. (2003). Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Medicine and Science in Sports and Exercise*, *35*(2), 333-341. https://doi.org/10.1249/01.mss.0000048831.15016.2a

Rodríguez-Rosell, D., Yáñez-García, J. M., Mora-Custodio, R., Pareja-Blanco, F., Ravelo-García, A. G., Ribas-Serna, J., & González-Badillo, J. J. (2020). Velocity-based resistance training: impact of velocity loss in the set on neuromuscular performance and hormonal response. *Applied Physiology Nutrition and Metabolism*, *45*(8), 817-828. https://doi.org/10.1139/apnm-2019-0829

Rodríguez-Rosell, D., Yáñez-García, J. M., Mora-Custodio, R., Sánchez-Medina, L., Ribas-Serna, J., & González-Badillo, J. J. (2021). Effect of velocity loss during squat training on neuromuscular performance. *Scandinavian Journal of Medicine & Science in Sports*, *31*(8), 1621-1635. https://doi.org/10.1111/sms.13967

Sabbahi, A., Arena, R., Kaminsky, L. A., Myers, J., & Phillips, S. A. (2018). Peak Blood Pressure Responses During Maximum Cardiopulmonary Exercise Testing: Reference Standards From FRIEND (Fitness Registry and the Importance of Exercise: A National Database). *Hypertension*, *71*(2), 229-236. https://doi.org/10.1161/hypertensionaha.117.10116

Sadler, S. G., Spink, M. J., Ho, A., De Jonge, X. J., & Chuter, V. H. (2017). Restriction in lateral bending range of motion, lumbar lordosis, and hamstring flexibility predicts the development of low back pain: a systematic review of prospective cohort studies. *BMC Musculoskelet Disord*, *18*(1), 179. https://doi.org/10.1186/s12891-017-1534-0

Safran, M. R., Seaber, A. V., & Garrett, W. E., Jr. (1989). Warm-up and muscular injury prevention. An update. *Sports Medicine*, *8*(4), 239-249. https://doi.org/10.2165/00007256-198908040-00004

San-Millán, I. (2023). The key role of mitochondrial function in health and disease. *Antioxidants*, *12*(4), 782. https://doi.org/10.3390/antiox12040782

Seeley, A. D., Giersch, G. E. W., & Charkoudian, N. (2021). Post-exercise Body Cooling: Skin Blood Flow, Venous Pooling, and Orthostatic Intolerance. *Frontiers in Sports and Active Living*, *3*, 658410. https://doi.org/10.3389/fspor.2021.658410

Sousa, N., Mendes, R., Abrantes, C., Sampaio, J., & Oliveira, J. (2013). A randomized 9-month study of blood pressure and body fat responses to aerobic training versus combined aerobic and resistance training in older men. *Experimental Gerontology*, *48*(8), 727-733. https://doi.org/10.1016/j.exger.2013.04.008

Sánchez-Medina, L., & González-Badillo, J. J. (2011). Velocity Loss as an Indicator of Neuromuscular Fatigue during Resistance Training. *Medicine & Science in Sports & Exercise*, *43*(9), 1725-1734. https://doi.org/10.1249/MSS.0b013e318213f880

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153-156. https://doi.org/10.1016/s0735-1097(00)01054-8

Taylor, J. L., Holland, D. J., Spathis, J. G., Beetham, K. S., Wisløff, U., Keating, S. E., & Coombes, J. S. (2019). Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. *Progress in Cardiovascular Diseases*, *62*(2), 140-146. https://doi.org/10.1016/j.pcad.2019.01.004

Unger, T., Borghi, C., Charchar, F., Khan, N. A., Poulter, N. R., Prabhakaran, D., Ramirez, A., Schlaich, M., Stergiou, G. S., Tomaszewski, M., Wainford, R. D., Williams, B., & Schutte, A. E. (2020). 2020 International Society of Hypertension Global Hypertension Practice Guidelines. *Hypertension*, *75*(6), 1334-1357. https://doi.org/doi:10.1161/HYPERTENSIONAHA.120.15026

Vaduganathan, M., Mensah, G. A., Turco, J. V., Fuster, V., & Roth, G. A. (2022). The Global Burden of Cardiovascular Diseases and Risk: A Compass for Future Health. *Journal of the American College of Cardiology*, *80*(25), 2361-2371. https://doi.org/10.1016/j.jacc.2022.11.005

Whelton, P. K., Carey, R. M., Aronow, W. S., Casey, D. E., Jr, Collins, K. J., Dennison Himmelfarb, C., DePalma, S. M., Gidding, S., Jamerson, K. A., Jones, D. W., MacLaughlin, E. J., Muntner, P., Ovbiagele, B., Smith, S. C., Jr, Spencer, C. C., Stafford, R. S., Taler, S. J., Thomas, R. J., Williams, K. A., Sr, ... Wright, J. T., Jr. (2018). 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation*, *138*(17), e426-e483. https://doi.org/10.1161/cir.0000000000000597

Williams, M. A., Haskell, W. L., Ades, P. A., Amsterdam, E. A., Bittner, V., Franklin, B. A., Gulanick, M., Laing, S. T., Stewart, K. J., American Heart Association Council on Clinical Cardiology, & American Heart Association Council on Nutrition, Physical Activity, and Metabolism (2007). Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*, *116*(5), 572-584. https://doi.org/10.1161/circulationaha.107.185214

Woods, K., Bishop, P., & Jones, E. (2007). Warm-up and stretching in the prevention of muscular injury. *Sports Medicine*, *37*(12), 1089-1099. https://doi.org/10.2165/00007256-200737120-00006