ESCUELA INTERNACIONAL DE DOCTORADO
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Autor:
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AUTORIZACIÓN DEL DIRECTOR DE LA TESIS PARA SU PRESENTACIÓN

El Dr. D. Pedro E. Alcaraz y el Dr. D. Tomás T. Freitas como Directores[(1)] de la Tesis Doctoral titulada "Match demands, players' characteristics, and neuromuscular performance across the season in elite futsal players." realizada por D. Konstantinos Spyrou en el Programa de Doctorado en Ciencias del Deporte, **autoriza su presentación a trámite** dado que reúne las condiciones necesarias para su defensa.

Lo que firmo, para dar cumplimiento al Real Decreto 99/2011 de 28 de enero, en Murcia a 22 de junio de 2023.

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To all, my best regards.

"I hope for nothing. I fear nothing. I am free.".

Nikos Kazantzakis (1883-1957)

This thesis is a compendium of 9 articles already published in peer-reviewed journals. The references for the abovementioned articles are as follows:

Article 1

Spyrou, K., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Physical and physiological match-play demands and player characteristics in futsal: a systematic review. Front Psychol, 2870.

Article 2

Spyrou, K., Freitas, T. T., Herrero-Carrasco, R., Marín-Cascales, E., & Alcaraz, P. E. (2023). Load Monitoring, Strength Training, and Recovery in Futsal: Practitioners' Perspectives Science and Medicine in Football, 1-8.

Article 3

Spyrou, K., Freitas, T. T., Marín-Cascales, E., Herrero-Carrasco, R., & Alcaraz, P. E. (2021). External match load and the influence of contextual factors in elite futsal. Biology of Sport, 39(2), 349-354.

Article 4

Spyrou, K., Freitas, T. T., Marín-Cascales, E., Herrero-Carrasco, R., & Alcaraz, P. E. (2021). Differences between official and non-official matches in worst-case scenarios in elite futsal players. Baltic Journal of Health and Physical Activity, 13(4), 5.

Article 5

Spyrou K., Alcaraz P. E., Martínez Serrano A., Marín-Cascales E, Ferioli D., Santis Contreras J. P., Freitas T. T. (2023). Analysis of the Countermovement Jump Variables according to Competitive Levels and Playing Positions in Futsal. Submitted

Article 6

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Article 7

Spyrou, K., Alcaraz, P. E., Marín-Cascales, E., Herrero-Carrasco, R., Cohen, D. D., & Freitas, T. T. (2023). Neuromuscular Performance Changes in Elite Futsal Players over a Competitive Season. The Journal of Strength & Conditioning Research, 37(5), 1111-1116.

Article 8

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Article 9

Spyrou, K., Alcaraz, P. E., Marín-Cascales, E., Herrero-Carrasco, R., Pereira, L. A., Loturco, I., & Freitas, T. T. (2022). Injury rates following the COVID-19 lockdown: A case study from an UEFA futsal champions league finalist. Apunts Sports Medicine, 57(213), 100377.

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ABSTRACT

Futsal, also known as five-a-side indoor soccer, is a team-sport that is becoming increasingly popular in the last year. In fact, the number of futsal-related investigations is growing in recent years. The current thesis aimed to describe and explore the match demands, players´ characteristics, and the neuromuscular performance across the season in futsal. The results of the present compendium of articles allowed concluding that futsal players are exposed to high physiological, neuromuscular, and biochemical stress during, immediately after, and post 24 h following the game, with significant differences on match demands between halves, but not considering contextual factors. Furthermore, official futsal matches presented higher intensity when compared to non-official matches. Regarding players' characteristics, professional futsal players cover greater distance, perform more high-intensity actions, and present lower standing time when compared to semi-professional players; moreover, the former present low percentages of body fat, high physiological and neuromuscular (i.e., sprinting, strength, and change of direction) capacities, and superior performance in the eccentric metrics of the countermovement jump (CMJ). Virtually all strength and conditioning coaches report monitoring training load, most of them through the use of subjective tools, utilize the neuromuscular and strength measurements to evaluate performance and monitor fatigue, and practice strength training and recovery strategies for the physical preparation in futsal. Elite futsal players presented significant positive changes in CMJ jump landing phases following the pre-season, however, concentric peak power in CMJ decreased significantly during the competitive season, and lastly, neuromuscular performance (i.e., sprint, horizontal jump, and CMJ kinetic variables), body composition, and relative number of non-contact injuries were significantly negative affected by detraining period derived from COVID-19 lockdown.

Keywords: five-a-side soccer, vertical jump, playing role, professional, team-sport.
Términos TESAURO: Fisiologia del Ejercicio; Fisiologia del Movimiento; Biomecanica.

RESUMEN

El fútbol sala es un deporte de equipo cada y vez más popular en los últimos años. De hecho, el número de investigaciones relacionadas con el fútbol sala está creciendo en los últimos años. La presente tesis tiene como objetivo describir y explorar las exigencias del partido, las características de los jugadores y el rendimiento neuromuscular a lo largo de la temporada en el fútbol sala. Los resultados del presente compendio de artículos permitieron concluir que los jugadores de fútbol sala están expuestos a un elevado estrés fisiológico, neuromuscular, y bioquímico durante, inmediatamente después y después de las 24 horas posteriores al partido, con diferencias significativas en las exigencias del partido entre las distintas mitades, pero sin tener en cuenta los factores contextuales. Además, los partidos oficiales de fútbol sala presentaron una mayor intensidad en comparación con los partidos no oficiales. En cuanto a las características de los jugadores, los jugadores profesionales de fútbol sala recorren mayor distancia, realizan más acciones de alta intensidad y presentan menor tiempo de pie en comparación con los jugadores semiprofesionales; además, los primeros presentan bajos porcentajes de grasa corporal, altas capacidades fisiológicas y neuromusculares (es decir, sprint, fuerza y cambio de dirección) y un rendimiento superior en la métrica excéntrica del salto con contra movimiento (CMJ). Prácticamente todos los preparadores físicos monitorizan la carga del entrenamiento, la mayoría de ellos mediante el uso de herramientas subjetivas, utilizan las mediciones neuromusculares y de fuerza para evaluar el rendimiento y monitorizar la fatiga, y practican estrategias de entrenamiento de fuerza y recuperación para la preparación física en fútbol sala. Los jugadores de élite de fútbol sala presentaron cambios positivos significativos en diferentes fases del salto CMJ después de la pretemporada, sin embargo, el pico de potencia concéntrica en CMJ disminuyó significativamente durante la temporada competitiva. Por último, el rendimiento neuromuscular (es decir, sprint, salto horizontal, y las variables cinéticas CMJ), la composición corporal, y el número relativo de lesiones sin contacto fueron significativamente afectados negativamente por el período de desentrenamiento derivado del confinamiento del COVID-19.

Palabras Clave: futsal, salto vertical, posición en la pista, profesional, deporte de equipo.
Términos TESAURO: Fisiologia del Ejercicio; Fisiologia del Movimiento; Biomecanica.

ABBREVIATIONS

The abbreviations of the units from the International System Units are not included in the following list as there are internationally accepted standards for their use. In addition, no abbreviations universally used in statistics are presented in this section.

ACC:	Acceleration
ACC_{HI}:	High-Intensity Acceleration
A.U:	Arbitrary Unit
CK:	Creatine Kinase
CMJ:	Countermovement Jump
CMJ_{height}:	Countermovement Jump Height
COD:	Change of Direction
COD_{HI}:	High-Intensity Change of Direction
CON:	Concentric
COM:	Center of Mass
D:	Defenders
Decem:	December
DEC:	Deceleration
DEC_{HI}:	High-Intensity Deceleration
Dif_{mean}:	Mean Difference
ECC:	Eccentric
EXPL-MOV:	Explosive Movements
FIET:	Futsal Intermittent Endurance Test
FIX:	Fixed-Period
FT-CT:	Flight Time-Contraction Time
GPS:	Global Positioning System

HR: Heart Rate

HR_{max}: Maximum Heart Rate

HR_{mean}: Mean Heart Rate

In_{se}: In-Season

Jan: January

La: Blood Lactate

La_{mean}: Mean Blood Lactate

LNFS: Liga Nacional de Fútbol Sala

MD: Match Day

NBA: National Basketball Association

Non-OFF: Non-Official

Oct: October

OFF: Official

PL: Player Load

$PL \cdot min^{-1}$: Player Load por minute

P: Pivot

Pre_{se}: Pre-Season

PRO: Professional

Post Pre_{se}: Post Pre-Season

REC: Recovery

RFD: Rate of Force Development

ROLL: Rolling Average

RPE: Rate of Perceived Exertion

RSI_{mod}: Reactive Strength Index Modified

Sep: September

SlgA: Salivary Immunoglobulin A

SLJ: Standing Long Jump

SEMI-PRO: Semi-Professional

S_{Vo2max}: Speed at Maximum Oxygen Uptake

S_{Vt2}: Speed Ventilatory Threshold

ST: Strength Training

S&Cc: Strength and Conditioning Coaches

TL: Training Load

VT_2: Ventilatory Anaerobic Threshold

VO_2: Oxygen Uptake

VO_{2max}: Maximum Oxygen Uptake

WCS: Worst-Case Scenarios

W: Winger

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I - INTRODUCTION

I. INTRODUCTION

Futsal, also known as five-a-side indoor soccer, is a team-sport officially authorized by Fédération Internationale de Football Association (FIFA) and is becoming increasingly popular all over the world. Futsal is characterized as a high-intensity intermittent sport that imposes high physical, technical, tactical, and psychological demands on players (1). The game is played five-a-side (i.e., four on-court players and one goalkeeper), in a 40×20 m court, with 3×2 m goal post and an unlimited number of substitutions. The maximum number of players in a squad for a match is 12 (10 court players and 2 goalkeepers). A futsal match consists of two halves of 20 min separated by a 10 min break. The game-clock is stopped for selected events, such as ball out of bounds, fouls or corners; thus, a competitive match may last between 75 and 90 min (2). During match-play, teams can request one time-out (1 min) in each half. Of note, the number futsal-related investigations is growing in the last years, and several studies have focused on: 1) describing competition demands via time-motion analysis (1, 3-8), or by reporting the physiological (1, 4, 7, 9, 10), neuromuscular (3, 7, 11, 12) and biochemical (9, 13-15) responses following a competitive match; and 2) monitoring the training load (TL) and evaluating performance across the season (16, 17).

Considering match demands, time-motion analysis is frequently used within team-sports to monitor and describe players' activity patterns and movements during competition (18-20). In this context, total distance covered, moderate- and high-speed running and the number and distance of sprints are the most commonly reported variables as they could help describe match and players' positional demands (19). In futsal, several studies have used video analysis and computer-based tracking systems to analyze match-play demands (1, 3-8). For example, Castagna et al. (4) investigated the game activities and showed that high-intensity running and sprinting accounted for 12% and 5% of the whole match duration, respectively, and players performed a sprint every 79 s with an average distance of 10.5 m, a duration of 1.95 s and a recovery (REC) between sprints of less than 40 s (4). According to Barbero-Alvarez et al. (1), who investigated the activity profile and match demands of an official (OFF) futsal match by video-system, the distance covered during a match was 4313 ± 2139 m and the mean distance covered per minute of play was 117.3 ± 11.6 m. Moreover, the mean distances walking and jogging were 397 m and 1792 m, respectively, which represents 9% and 40% of the total mean distance covered (1). The mean distance in medium-intensity activity was 1232 m (28.5% of total match), high-intensity running was 571 m (13.7%), and sprinting was 348 m (8.9%) (1).

However, it is important to highlight that all previous information on futsal match demands were derived from time-motion analysis, and only two studies (24, 25) used wearable technology (i.e., global positioning system [GPS] or accelerometry) during the games, highlighting the need for further research regarding the description of the external loads experienced by players during OFF competition. Furthermore, when it comes to futsal, the influence of contextual factors (i.e., opposing team's ranking, match outcome, and location) has been addressed mainly from a technical-tactical perspective (26) but literature is scarce regarding external match load metrics, particularly using wearable technology-derived variables. This information may result extremely helpful for coaches as determining match demands based solely on video-analysis tools may be considerably time-consuming and limit the proper quantification of non-locomotor activities influencing sports performance (e.g., impacts or collisions) (27). As such, a better understanding of match external load monitored via wearable technology may help coaches and sports scientists to prescribe training sessions more related to the actual efforts and demands of competition, thus enhancing performance and potentially reducing the risk of injury. Furthermore, the type of matches in futsal (i.e., OFF and Non-OFF) have not been extensively researched and it is yet to be clarified how match-type may influence match-play demands. From a coaching perspective, these are important aspects to consider, about players′ preparedness for training and competition loads during the season, and sport practitioners should be conscious about the external match load depending on contextual factors (i.e., opposing team's ranking, match outcome, and location) and the type of the game (i.e., OFF and Non-OFF).

When quantifying the demands of a match, different methods (i.e., "average approach" or "worst-case scenarios" [WCS] methods) have been used to measure and analyze the mechanical stress that players are exposed to during competition. The WCS approach relates to the quantification of the most intense period of the game or training (28) and is becoming increasingly popular in team-sports, such as soccer (29, 30), rugby (28), Australian football (31), futsal (32), and field- and ice-hockey (33, 34), to assess fluctuations in match demands by dividing time-play into discrete "epochs". The WCS may be considered more accurate to quantify the most intense periods of the game, because the "average approach" may overlook variations and obscure the most intense periods of the play (35). Depending on the availability of wearable technology (i.e., GPS vs accelerometry) and sport (i.e., indoor vs outdoor), player load (PL), PL·min^{-1}, total distance, and high-speed running have been the most commonly investigated variables with time windows ranging from 30 s to 10 min in length (28-33). Within the WCS approach, the fixed-period method (FIX) was first developed (36), and consisted of splitting the time into fixed-periods (e.g., 1–30 s, 31–60 s, etc.). However, quantifying WCS by rolling average (ROLL) is considered more accurate, as this technique detects the exact period (e.g., 1–30 s, 2–31 s, etc.) in which players reached the highest intensity (37, 38). Still, when it comes to futsal, literature is scarce about the quantification of WCS of different matches (i.e., OFF and Non-OFF) and using different methods (i.e., ROLL and FIX).

Understanding match-play demands is important for player´s health (i.e., training and game availability and physical preparedness) and team´s success. However, this is just a part of the puzzle when it comes to players' physical preparation. In this regard, strength and conditioning coaches (S&Cc) commonly evaluate neuromuscular performance, such as jumping ability, across the season in order to obtain further information on their athletes' performance status. This can be used to avoid the detrimental effects of the training and to better assess the game stress that players exposed to (39, 40). It has been shown that the successful application of vertical ground reaction forces (i.e., as in vertical jumping) may play a significant role in multiple athletic actions (e.g., sprinting or change of direction [COD]) (41). For example, Ribeiro et al. (42) recommended that vertical jump testing (i.e., countermovement jump [CMJ]) should be conducted as it may help understand players' neuromuscular readiness to compete which has implications for their match performance and, consequently, for the final team result. For that reason, and considering that lower-body powerful actions are determinant during the match, several researchers (43-56) have investigated power related capacities of futsal players. However, considering the different levels of futsal players, Naser and Ali, (50) identified no significant differences in CMJ height (CMJ_{height}) between elite and sub-elite futsal players. Similar results obtained by Sekulic et al (181), as top-level players outperformed high-level players in reactive strength index (RSI) and broad jump, but not in vertical jump height. Based on the previous studies (50, 57, 58) that have assessed vertical jump height, it appears that elite futsal players do not display greater jumping ability than their sub-elite counterparts, potentially due to the limited influence of jumping ability in the game. However, it is important to consider that CMJ_{height} may not be sensitive enough to detect changes in stretch shortening cycle performance or the contractile system function since evidence indicates that athletes may change their movement strategy to maintain or even increase jump height (40, 59). Therefore, a more comprehensive kinetic analysis of the CMJ force time curve and its derivative impulse, power, velocity, and displacement metrics could enhance the difference of between athlete´s level neuromuscular performance (60).

The typical competitive futsal season consists of ~50 regular matches considering national and international competitions over a span of ~8.5 months, with a frequency of 1–3 games per week. As mentioned above, PRO futsal players face up to high physical stress (17, 61) and usually complete daily or twice-a-day sessions for games' preparation, covering as much as ~10 km (on average) at high and very-high intensities during a typical weekly microcycle (62). For this reason, training and competition loads can lead to not only acute neuromuscular fatigue (i.e., failure of the musculoskeletal system to maintain the required force or power output) (63), but also residual (i.e., 24 – 72 h following exercise (64)), and potentially chronic fatigue (i.e., overtraining syndrome) (65), throughout the season, if appropriate individual tailor-made training programs (e.g., adjusting REC times or limiting on-court weekly distance) are not considered.

However, recently a number of studies (66-68) have shown that a more comprehensive analysis of kinetic variables during the jump-land cycle is needed to detect neuromuscular impairments associated with acute or residual fatigue. Similarly, adaptive responses following periods of training (40, 59) or detraining (66, 69) may require a thorough analysis of selected CMJ metrics to identify alterations in neuromuscular status during the season that are not detected by monitoring jump height alone. Several investigations (67, 68, 70-74) have examined neuromuscular performance at several timepoints during the season and shown that, overall, physical abilities tend to be maintained or decrease across the season. Nevertheless, few studies (75-77) in futsal have investigated potential changes in physical capacities across the season. Particularly, in PRO futsal players, the influence of training and competition stress on sprint, horizontal, and vertical jump performance and on CMJ kinetic variables (assessed pre-season [Pre_{se}], post Pre_{se}, and multiple times across the in-season [In_{se}]) has not been examined.

As mentioned above, investigating about the neuromuscular performance during the season is highly important for monitoring the player´s adaptations to training and competition stress but also to reduced training periods (as seen at the beginning of 2020 [March – May], due to the SARS-CoV-2 [COVID-19] pandemic). Understanding how athletes respond under such circumstances is equally important for minimizing detrimental effects and planning an appropriate individual tailor-made training program. Considering that, and to paint a full picture of the neuromuscular performance profile of professional futsal players, complementary research about the effects of detraining periods, such as COVID-19 lockdown period, on neuromuscular performance, body composition, and number of injuries in futsal is warranted.

Considering all the above, the present compendium of articles aimed: 1) to systematically review the literature on futsal match demands and players characteristics in futsal; 2) to describe practitioner´s perspective about the TL, monitoring players' performance and fatigue assessment practices, and strength training (ST) and REC strategies in PRO futsal players; 3) to compare the external load metrics between halves, contextual factors (i.e., opposing team's ranking, match outcome, and location) using average-approach, and then the WCS between OFF and Non-OFF futsal matches; 4) to compare the differences on CMJ jump landing metrics between PRO and semi-professionals (SEMI-PRO) players and amongst playing positions; 5) to examine neuromuscular performance (i.e., sprint, vertical and horizontal jump) during Pre_{se}, early In_{se}, and across the season; and lastly, 6) to study the neuromuscular performance (i.e., sprint, horizontal jump, and CMJ jump landing phase variables), body composition, and the number of non-contact injuries before and after long detraining periods, as observed during the COVID-19 pandemic.

II - OBJECTIVES

II. OBJECTIVES

3.1. GENERAL OBJECTIVES

Considering the hypotheses previously outlined, and within the general objectives of the current thesis, the present compendium of articles aimed to describe and explore the match demands, players´ characteristics, and the neuromuscular performance across the season in futsal.

3.2. SPECIFIC OBJECTIVES

The specific objectives outlined for each of the studies included in the present thesis are presented below:

Study 1:

-To systematically review the literature on futsal match demands.

-To systematically review the literature on match demands differences between PRO and SEMI-PRO players.

-To systematically review the literature on the physiological, neuromuscular, and biochemical responses during competition, between the two halves, immediately, and post 24 h following match-play.

-To systematically review the literature on futsal players´ physiological and neuromuscular characteristics.

Study 2:

-To describe the TL monitoring and player's physical capacities evaluation practices across the season.

-To describe the characteristics and prescription of ST during normal and congested weeks.

-To describe the REC strategies and methods following “home” or “away” games.

Study 3:

-To compare the external load metrics (PL, PL·min^{-1}, ACC_{HI}, DEC_{HI}, EXPL MOV, and COD_{HI}) between halves.

-To measure the external load metrics (PL, PL·min^{-1}, ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI}) regarding contextual factors (i.e., team’s ranking, match result, and location).

Study 4:

-To compare the WCS (PL·min^{-1}) between OFF and Non-OFF futsal matches.

-To examine the WCS (PL·min^{-1}) amongst different time intervals (i.e., 30 1, 3, and 5 min).

-To compare the differences on WCS (PL·min^{-1}) calculated by ROLL and FIX method.

Study 5:

-To compare the differences on CMJ jump landing metrics (CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity) between PRO and SEMI-PRO players.

-To compare the differences on CMJ jump landing metrics (CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity) amongst playing positions (D, W, and P).

Study 6:

-To examine neuromuscular performance (i.e., sprint and CMJ jump landing phase variables [CMJ_{height}, RSI_{mod}, ECC and CON power, force, velocity, duration, ECC Dec RFD, COM displacement, and landing peak force]) during Pre_{se} and early In_{se} period.

Study 7:

-To evaluate the neuromuscular performance across all metrics (i.e., sprint, SLJ, and CMJ jump landing phase variables [CMJ_{height}, ECC and CON peak power and velocity, duration, COM displacement, landing peak force, and RFD to peak force]) across In_{se}.

Study 8:

-To study the neuromuscular performance (i.e., sprint, horizontal jump, and CMJ jump landing phase variables [CMJ_{height}, ECC and CON impulse, peak power, and velocity, ECC RFD, and landing peak force and RFD to peak force]) and body composition pre- and post- lockdown period derived by COVID-19.

Study 9:

-To present the relative number of non-contact injuries before and after the season intermission (i.e., post-lockdown) derived by COVID-19.

III - HYPOTHESES

II. HYPOTHESES

2.1. GENERAL HYPOTHESES

Following an overview of the current state of the literature, it was hypothesized that futsal match demands would be negatively affected on the second half of the game with respect to the first and considering different contextual factors. Moreover, player´s characteristics would be superior in PRO futsal players when compared to SEMI-PRO counterparts. Lastly, it was hypothesized that player´s neuromuscular performance would be diminished immediately, and post 24 h following match-play and would fluctuate according to the phase of the season.

2.2. SPECIFIC HYPOTHESES

The specific hypotheses outlined for each of the studies included in the present thesis are presented below:

Study 1:

-A review of the literature would show that futsal players perform intermittent high-intensity activities with a great number of acceleration (ACC), deceleration (DEC), COD, and sprints, with short REC times between them during match-play.

-The systematic review would allow concluding that elite futsal players covering higher distance, performing more high-intensity actions, and presenting lower standing time when compared to sub-elite players.

-A review of the literature would display that futsal match-play produces important decrements in physiological, neuromuscular, and biochemical responses between the two halves, immediately, and post 24 h following match-play.

-The systematic review would present that futsal players would present low percentages of body fat, and high level of physiological (i.e., VO_{2max}) and neuromuscular (i.e., sprinting, strength, jumping, and COD) capacities.

Study 2:

-No leading hypothesis was taken for the questionnaire.

Study 3:

-External load metrics (PL, $PL \cdot min^{-1}$, high-intensity ACC [ACC_{HI}], DEC [DEC_{HI}], explosive movements (EXPL-MOV), and high-intensity [COD_{HI}]) would be lower in the 2nd half when compared to the 1st half.

-External load metrics (PL, $PL \cdot min^{-1}$, ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI}) would be higher against top-ranked teams, in "wins", and during "home" games.

Study 4:

-WCS ($PL \cdot min^{-1}$) would be higher in OFF when compared to Non-OFF matches.

-WCS ($PL \cdot min^{-1}$) would be higher in smaller (e.g., 30 s and 1 min) rather than larger time-epochs (e.g., 3 and 5 min).

-WCS ($PL \cdot min^{-1}$) would be higher when calculated by ROLL in comparison with FIX method.

Study 5:

-PRO players would present higher performance in the CMJ metrics (CMJ_{height}, center of mass [COM] displacement, flight-contraction time, modified RSI [RSI_{mod}], and eccentric [ECC] and concentric [CON] duration, peak force, power, and velocity) when compared to SEMI-PRO players.

-No differences on CMJ metrics (CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity) would be found between playing positions (i.e., defender [D], winger [W], pivot [P]).

Study 6:

-Neuromuscular performance (i.e., sprint and CMJ jump landing phase variables [CMJ_{height}, RSI_{mod}, ECC and CON power, force, velocity, duration, ECC DEC rate of force development [RFD], COM displacement, and landing peak force]) would increase following Pre_{se} and then, due to the demands of competition would be maintained or slightly decrease during the early In_{se} period.

Study 7:

-Neuromuscular performance would decline across all metrics (i.e., sprint, standing long jump [SLJ], and CMJ jump landing phase variables [CMJ_{height}, ECC and CON peak power and velocity, duration, COM displacement, landing peak force, and RFD to peak force]) as the season progressed.

Study 8:

-Neuromuscular performance (i.e., sprint, horizontal jump, and CMJ jump landing phase variables [CMJ_{height}, ECC and CON impulse, peak power, and velocity, ECC RFD, and landing peak force and RFD to peak force]) and body composition would be negatively affected by the lockdown period derived by COVID-19.

Study 9:

-The relative number of non-contact injuries would be greater after the season intermission (i.e., post-lockdown) derived by COVID-19.

IV – GENERAL OVERVIEW OF THE STUDIES

IV. GENERAL OVERVIEW OF THE STUDIES

STUDY 1:

PHYSICAL AND PHYSIOLOGICAL MATCH-PLAY DEMANDS AND PLAYER CHARACTERISTICS IN FUTSAL: A SYSTEMATIC REVIEW

Abstract

Futsal, also known as five-a-side indoor soccer, is a team-sport that is becoming increasingly popular. In fact, the number of futsal-related investigations is growing in recent years. This review aimed to summarize the scientific literature addressing the match-play demands from the following four dimensions: time-motion/external load analysis and physiological, neuromuscular, and biochemical responses to competition. Additionally, it aimed to describe the anthropometric, physiological, and neuromuscular characteristics of elite and sub-elite male futsal players, contemplating the differences between competition levels. The literature indicates that elite futsal players cover greater total distance with higher intensities and perform a greater number of sprints during match-play when compared to sub-elite players. The physiological demands during competition are high (average intensity of ≥85% maximum heart rate (HR_{max}) and ~80% VO_{2max}), with decrements between the two halves. Research suggests that neuromuscular function decreased and hormonal responses increased up to 24 h after the match. Considering anthropometric characteristics, players present low percentage of body fat, which seems commonplace among athletes from different on-court positions and competition levels. Elite players display greater values and at VO_{2max} with respect to sub-elite competitors. Little is known regarding elite and sub-elite futsal players' neuromuscular abilities (strength, jumping, sprinting, and COD). However, it appears that elite players present better sprinting abilities compared to lower-level athletes. Futsal players aiming to compete at the highest level should focus on developing maximal speed, lower-body power and strength, aerobic capacity, and lean muscle mass.

STUDY 2:

LOAD MONITORING, STRENGTH TRAINING, AND RECOVERY IN FUTSAL: PRACTITIONERS' PERSPECTIVES

Abstract

This study aimed to describe the current practices in futsal regarding a variety of topics related to performance and injury risk mitigation. Thirty-seven coaches from Spain and Portugal completed a questionnaire consisting of 28 closed questions organized in four categories: a) background information; b) TL monitoring and assessment of players´ physical qualities; c) ST practices; and d) REC methods. The results showed that coaches varied in experience (1 – 8 years) and age (20 years – >50 years). Overall, 97.3% of the participants declared monitoring TL, with rate of perceived exertion (RPE), heart rate (HR) monitors and wearable technology being used by 86.5%, 40.5% and 37.8%, respectively. Neuromuscular and strength testing are the most common practices to evaluate performance and fatigue during the season. ST is a significant component in futsal, being performed 3 times/week during the Pre_{se} and In_{se}. ST is prescribed via %1RM–XRM (59.5%), velocity-based training (21.7%), repetitions in reserve (18.9%), until failure (10.8%), and circuit training (2.7%). "Better Monitoring", "More Individualized", "Better Facilities", "More Staff", and "More Time" were the main aspects to improve ST. Multiple post-match REC strategies are used, with durations ranging from 0 – 15 to 16 – 30 min independently of game location.

STUDY 3:

EXTERNAL MATCH LOAD AND THE INFLUENCE OF CONTEXTUAL FACTORS IN ELITE FUTSAL

Abstract

Quantifying external load during futsal competition can provide objective data for the management of the athlete's performance and late-stage rehabilitation. This study aimed to report the match external load collected via wearable technology according to time periods (i.e., halves) and contextual factors (i.e., team's ranking, match result, and location) in elite futsal. Nine PRO male players used a GPS-accelerometer unit during all games of the 2019–2020 season. PL, PL·min^{-1}, ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI} data were collected. On average, players displayed values of: total PL 3868 ± 594 arbitrary unit (a.u); PL·min^{-1}: 10.8 ± 0.8 a.u; number of ACC_{HI}: 73.3 ± 13.8, DEC_{HI}: 68.6 ± 18.8, EXPL-MOV: 1165 ± 188 and COD_{HI}: 173 ± 29.1. A moderate and significant decrease was found in the 2nd half for total PL ($p = 0.03$; ES = 0.52), PL·min^{-1} ($p = 0.001$; ES = 1.16), DEC_{HI} ($p = 0.001$; ES = 0.83), and EXPL-MOV ($p = 0.017$; ES = 0.58) compared to the 1st half. Small and nonsignificant differences were found between contextual factors. In summary, this study indicates that futsal players are exposed to high-intensity mechanical external loads, and perform a great number of ACC_{HI}, DEC_{HI}, EXPL-MOV and COD_{HI}, without being influenced by the team ranking, result and match location. Coaches and sports scientists are advised to implement speed-power, DEC, and COD activities in the training sessions, and may use these reference values to design specific training and return-to-play plans.

STUDY 4:

DIFFERENCES BETWEEN OFFICIAL AND NON-OFFICIAL MATCHES IN WORST-CASE SCENARIOS IN ELITE FUTSAL PLAYERS

Abstract

Background: This study aimed to compare the WCS between OFF and Non-OFF matches, in different time-periods in an elite futsal team.

Material and methods: Twenty-six games were divided into OFF (n = 13) and Non-OFF (n = 13). The WCS were calculated using: two methods, ROLL and FIX; four-length epochs (30 s, 1, 3, and 5 min); and PL·min^{-1}.

Results: Considering ROLL, significant and small differences were found in PL·min^{-1}, with higher intensity in 30 s ($p = 0.001$; ES = -0.53) and 1 min ($p = 0.001$; ES = -0.47) in OFF when compared to Non-OFF, but nonsignificant and small to trivial changes in 3 min ($p = 0.060$; ES = -0.23) and 5 min ($p = 0.605$; ES = -0.06) were observed. Regarding FIX, significant and small changes were obtained, with higher intensity in OFF in all time-periods when compared to Non-OFF. Significant differences were found between the two methods (ROLL vs FIX) in 30 s, 1 and 3 min, but not in 5 min. Significant differences, with lower PL·min^{-1}, were observed with increasing time-windows from both methods ($p = 0.001$).

Conclusions: In summary, OFF matches present higher WCS than Non-OFF ones when considering short time-periods, and the FIX method could underestimate the "actual intensity" of the match compared to ROLL.

STUDY 5:

ANALYSIS OF THE COUNTERMOVEMENT JUMP VARIABLES ACCORDING TO COMPETITIVE LEVELS AND PLAYING POSITIONS IN FUTSAL

Abstract

The aims of this study were to compare several countermovement jump (CMJ) kinetic variables between PRO and SEMI-PRO futsal players and examine the differences amongst playing positions. CMJ performance from 56 male futsal players (25.2 ± 4.8 years; weight: 74.4 ± 6.4 kg) was analysed. Players were separated into PRO (n = 29; 27.0 ± 4.4 years; 75.4 ± 6.0 kg) and SEMI-PRO (n = 27; 22.7 ± 4.3 years; 73.1 ± 6.8 kg), and according to playing position: D (n = 16; 25.4 ± 3.7 years; 75.2 ± 6.0 kg), W (n = 26; 23.5 ± 4.5 years; 72.0 ± 6.9 kg), and P (n = 14; 28.0 ± 5.6 years; 77.8 ± 4.3 kg). Linear mixed models and effect sizes were used for the analyses based on the mean of two jumps for each variable. PRO players presented a higher COM displacement (p = 0.002, ES = 0.83), greater ECC absolute (p = 0.019, ES = 0.61) and relative peak power (p = 0.046, ES = 0.52), and achieved greater ECC peak velocities (p = 0.004, ES = 0.76) when compared to SEMI-PRO. Non-significant and trivial-to-small differences were observed in all the other CMJ variables according to the competitive level and playing position. ECC capabilities (i.e., deeper COM displacement, greater ECC absolute and relative peak power, and peak velocity) during vertical jump seem to differentiate PRO and SEMI-PRO players. However, CMJ variables do not discriminate amongst playing positions in futsal players.

STUDY 6:

CHANGES IN NEUROMUSCULAR PERFORMANCE DURING PRE AND EARLY COMPETITIVE SEASON IN ELITE FUTSAL PLAYERS

Abstract

This study aimed to investigate the variations on vertical jump and sprint performance during the first weeks of a futsal season. Eleven elite futsal players, competing in Spain's 1st Division over the season 2019-2020, performed two CMJ on a force platform at three different timepoints: before the Pre_{se}; immediately after the Pre_{se}; and early In_{se}. A one-way repeated measure ANOVA with Post-hoc pairwise comparisons and effect sizes (ESs) were used. Non-significant and trivial changes were observed in CMJ_{height} ($p = 0.830$; ES = 0.12) among the three timepoints. However, significant and moderate positive changes amongst seasons were found in specific CMJ kinetic variables such as: RSI_{mod} ($p = 0.011$; ES = 0.60), ECC peak force ($p = 0.011$; ES = 0.65), ECC DEC RFD ($p = 0.008$; ES = 0.60), ECC duration ($p = 0.040$; ES = 0.89), and CON ($p = 0.030$; ES = 0.45) and landing peak force ($p = 0.012$; ES = 0.68). A significant time interaction was observed in sprint performance ($p = 0.038$; ES = 0.58); however, non-significant and small-moderate changes were detected in sprint time when compared among periods. In conclusion, CMJ kinetic variables should be incorporated and analyzed alongside more standard measures (CMJ_{height}) to monitor performance in elite futsal players, as changes of substantial magnitude were observed in phase-specific metrics during the Pre_{Se} and the initial stages of the competitive calendar.

STUDY 7:

NEUROMUSCULAR PERFORMANCE CHANGES IN ELITE FUTSAL PLAYERS OVER A COMPETITIVE SEASON

Abstract

A PRO futsal season imposes a great amount of physiological and mechanical stress on players. The main aim of this study was to examine the changes in neuromuscular performance qualities across the season. Ten PRO male players performed a 10 m sprint, SLJ, and CMJ during the competitive season (i.e., every ~5 weeks from Sep to Jan). A one-way repeated measure ANOVA with Post-hoc pairwise comparisons and effect sizes (ESs) were used to analyze potential differences amongst these assessments. A significant and large decline was found in CON peak power ($p = 0.040$; ES = 1.24). A non-significant and moderate decrease was observed in sprint ability ($p = 0.155$; ES = 1.03), CMJ_{height} ($p = 0.175$; ES = 1.00), and SLJ distance ($p = 0.164$; ES = 1.03). Regarding other CMJ kinetic variables, non-significant and moderate changes were found. In summary, considering the neuromuscular performance tests and variables assessed, only CON peak power in CMJ decreased significantly across the season; however, non-significant decrements were observed in sprinting time, SLJ, CMJ_{height} and other kinetic metrics. CMJ variables during the jump-land cycle should be incorporated alongside more traditional measures (e.g., jump height) to monitor performance during the season.

STUDY 8:

EFFECTS OF THE COVID-19 LOCKDOWN ON NEUROMUSCULAR PERFORMANCE AND BODY COMPOSITION IN ELITE FUTSAL PLAYERS

Abstract

Recent world events (i.e., Covid-19 pandemic) led to an unparalleled situation in sports. Players were forced to stay at home for a prolonged period and not allowed to use their team's training facilities or even exercise outdoors. The main aim of this study was to examine the effects of the Covid-19 lockdown on neuromuscular performance and body composition in futsal players. Ten elite male players performed a 10 m sprint, horizontal and vertical jump, and body composition measurements before and after the quarantine (i.e., 70 days). Pre-post confinement differences in horizontal jump distance, CMJ variables, sprinting time and body composition were analyzed by a paired sample T-Test and effect sizes (ES). A large and significant decline was observed in sprint ability ($p = 0.004$; ES = 1.31). Small and non-significant differences were found in horizontal jump performance ($p = 0.243$; ES = -0.39). Non-significant differences were observed in CMJ_{height} ($p = 0.076$; ES = -0.63) but moderate to large significant declines were found in CMJ ECC DEC impulse, RFD, peak power, velocity and landing peak force ($p \leq 0.05$; ES = -0.52 – 1.23). Finally, trivial and non-significant differences were obtained on body composition parameters. In summary, sprint performance and specific CMJ kinetic variables were significantly affected by long-term reduced training, while vertical jump height and horizontal jump distance and body composition were not. Practitioners are advised to implement efficient sprint- and ECC-oriented training strategies to optimize return to competition after prolonged detraining periods.

STUDY 9:

INJURY RATES FOLLOWING THE COVID-19 LOCKDOWN: A CASE STUDY FROM AN UEFA FUTSAL CHAMPIONS LEAGUE FINALIST

Abstract

Introduction: Recently, a pandemic disease (i.e., Covid-19) arose complicated conditions for players, clubs, and sports competitions. Most European countries postponed or canceled their respective leagues as players were forced into a long-term lockdown. This case study presents and compares the absolute and relative non-contact lower-limb injury rates and characteristics before and after the lockdown from a Finalist of the UEFA Futsal Champion League.

Material and methods: Thirteen elite futsal players (age: 27 ± 2.8 years old; body mass: 76 ± 5.4 kg; height: 1.79 ± 0.1 m; body fat: 9 ± 1.6%) participated in this study. Injury severity, location, type, and mechanism were recorded. Data from the 6 weeks pre- and post-lockdown were collected, and injury rates were expressed per 1,000 training and match hours.

Results: Chi-Square tests revealed a significant difference ($p = 0.039$) in the distribution of the number of injuries between the two moments. No overuse and non-contact injuries were observed during the 6 weeks before the lockdown. Nevertheless, 38% (i.e., 5) of the players suffered minimal severity (i.e., ≤ 3 days of court absence) overuse injuries in the hip/groin and thigh muscles post-home-confinement.

Conclusions: Elite male futsal players sustained a substantially higher number of lower-body non-contact injuries after the lockdown. Practitioners should implement a thorough analysis of players' neuromuscular qualities and fatigue to identify individual training and REC needs and, thus, prescribe more tailored injury-reduction programs.

V – STUDY 1

V. STUDY 1

PHYSICAL AND PHYSIOLOGICAL MATCH-PLAY DEMANDS AND PLAYER CHARACTERISTICS IN FUTSAL: A SYSTEMATIC REVIEW

5.1. INTRODUCTION

Futsal, also known as five-a-side indoor soccer, is a team-sport officially authorized by FIFA and is becoming increasingly popular all over the world. It is characterized as a high-intensity intermittent sport that imposes high physical, technical, tactical, and psychological demands on players (1). The game is played five-a-side (i.e., four on-court players and one goalkeeper), in a 40×20 m court, with 3×2 m goal post and an unlimited number of substitutions. The maximum number of players in a squad for a match is 14 (a maximum of 9 substitutes per team). A futsal match consists of two halves of 20 min separated by a 10 min break. Given that the game-clock is stopped for some events (i.e., ball out of the court, faults, corners), a competitive match may last between 75 and 90 min (2). During match-play, teams can request one timeout (1 min) in each half.

Of note, the number of futsal-related investigations is growing in recent years. Several studies have described competition demands (1, 3-7, 24, 25, 80-83) by reporting the physiological (1, 4, 7, 9, 10, 25, 81, 84), neuromuscular (3, 7, 24, 82) or biochemical responses (9, 13, 15) following a competitive match. In addition, different authors have shown particular interest in describing the characteristics of futsal players such as anthropometrics (13, 45, 46, 51, 85-90), physiological (1, 9, 43-45, 47, 49-52, 54, 55, 77, 81, 82, 84, 85, 88, 91-105) and neuromuscular qualities (43-56, 84, 106-111). This is extremely important, since understanding the match position-specific demands and the physical requirements for elite futsal players is the foundation for planning an effective training program. With this is in mind, the objective of this review is to update and summarize the current state of literature on the match-play demands, physical, physiological, and neuromuscular characteristics of elite futsal players, and to present the differences between competition levels. To the best of authors' knowledge, this is the first systematic review to simultaneously characterize futsal match-play demands through different approaches (i.e. time-motion analysis and wearable technology external load data, physiological, neuromuscular and biochemical responses) and describe the players' physical attributes.

5.2. METHODS

5.2.1. Study Design

The present study is a systematic review focused on the match-play demands and players' characteristics (i.e. anthropometrics, physiological and neuromuscular) at different levels of competition in futsal. The review was performed in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (112) and did not require Institutional Review Board approval.

5.2.2. Search Strategy

A systematic search was carried out in PubMed, Web of Science and SportDiscus, all high-quality databases that assure a strong bibliographic support. The search strategy considered all the related articles published until July 25th, 2020. To ensure that all studies related to this topic were identified, a broad and general search was conducted by using solely the following keywords in the search strategy: ("futsal" OR "indoor soccer" OR "five-a-side soccer"). All titles and abstracts from the search were cross-referenced to identify duplicates and any missing studies, and then screened for a subsequent full-text review. The search was performed independently by two authors (KS, EMC) and any disagreement was resolved by a third party (TTF).

5.2.3. Inclusion and Exclusion Criteria

The review included cross-sectional and longitudinal studies published in English considering PRO futsal players. The studies were included if they comprised: 1) elite male futsal players; 2) sub-elite players, but only when compared to superior competition levels; 3) players ≥ 20 years old; and 4) variables related to the physical and physiological match-play demands and player characteristics (i.e., anthropometrics, physiological, or neuromuscular) were reported. Importantly, in the context of the current review, players were classified as elite if they competed in the National Team or 1st Division of their respective countries or in the 2nd Division of Spain, Portugal, Italy or Russia. All the players that did not meet this standard were considered to be sub-elite.

Studies were excluded if: 1) participants were ≤ 19 years old; 2) were female; 3) only sub-elite/state level players participated in the study; 4) the division in which players competed was not detailed in the study (e.g., the players were referred to as "elite" but the article did not clearly mention that players competed in 1st Division); 5) non-English language; 6) the methodological quality assessment score was ≤ 8; and 7) the study consisted on a review or a conference paper.

5.2.4. Study Selection

The initial search was conducted by two researchers (KS, EMC). After the removal of duplicates, an intensive review of all the titles and abstracts obtained was completed and the ones not related to the review´s topic were discarded. Following the systematic screening process, the full-version of the remaining articles was read. All studies not meeting the inclusion criteria were then excluded.

5.2.5. Data Extraction

Two reviewers (KS, EMC) extracted the following data from the included studies: number and competitive level of the participants; match-play time-motion and physiological data; players' physiological and neuromuscular characteristics, the tests performed, measurement tools used and outcome units. As the aim of the present review was not to investigate or determine the effects of different training programs on futsal players' physical qualities, in the studies in which interventions were used, the baseline values (i.e., pre-intervention) were extracted and reported in the respective tables in the Results section. In case the manuscript did not present numerical description of the data, the software GetData Graph Digitizer 2.26 (free software downloaded from http://getdata-graph-digitizer.com) was used to extract the outcome values from the articles' figures or graphs.

5.2.6. Methodological Quality Assessment

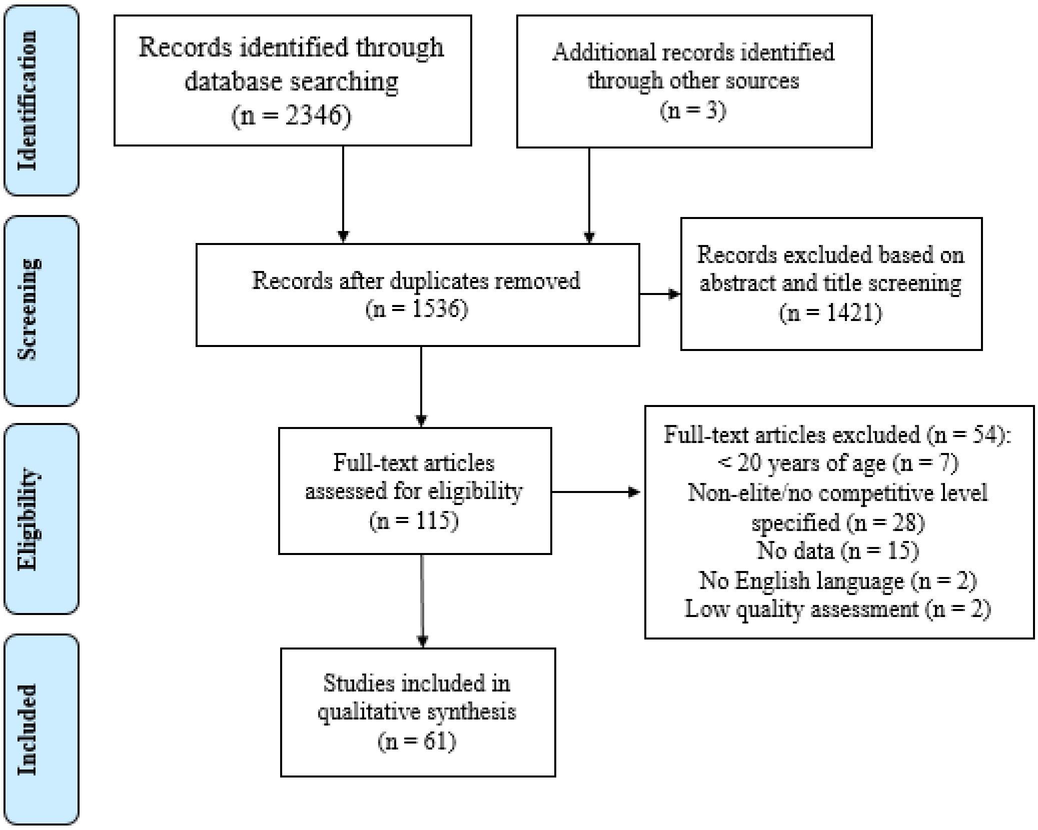
The methodological quality of the included studies was evaluated separately by two researchers (KS, EMC) using the modified scale of Downs and Black (113). Disputes were resolved by a third party (TTF). Of the 27 criteria, 12 were applied according to the study's design, as observed in similar research previously published (114, 115).

5.3. RESULTS

5.3.1. Search Results

Figure 1 depicts the PRISMA flow diagram of the search and selection process of the studies. The initial databases yielded 2346 citations and 3 additional records were added through other sources. After duplicate removal, 1536 articles remained. Upon title and abstract screening, 115 were left for the full-text review. Of the 115 articles reviewed, 61 met the criteria for the systematic review. Of the 61 the studies, 12 included time-motion analysis and match external load data, 8 reported physiological responses to competition, 4 presented neuromuscular responses, and 3 considered biochemical responses. Regarding players' characteristics, 10 studies included anthropometric outcomes, 33 detailed physiological variables, and 21 investigated neuromuscular capabilities. Most of the studies were included in more than one section of the manuscript.

Figure 1 Flow diagram



5.3.2. Match Demands

5.3.2.1. Time-Motion Analysis and External Match Load

Time-motion analysis and external load tracking is frequently used within team-sports to monitor and describe players' activity patterns and movements during competition (18-20). In this context, total distance covered, average speed, the number and distance of sprints, ACC and DEC are the most commonly reported variables as they help describe match and players' positional demands (116).

In futsal, several studies have used video analysis and computer-based tracking systems but only two studies have used wearable technology (GPS or accelerometer) to analyze match-play demands (Table 1) (1, 3-7, 24, 25, 80-83). Most recently, Ribeiro et al. (24) analyzed a series of kinematic, mechanical and metabolic variables during match-play using GPS wearable devices (WIMU PROTM, Realtrack Systems, Almeria, Spain) and found that the total distance covered was 3749 ± 1123 m and sprinting (≥ 18.0 $km \cdot h^{-1}$) distance corresponded to 135 ± 54 m. Moreover, the authors reported that futsal players performed a great number of ACC_{HI} (87 ± 49) and DEC_{HI} (80 ± 32), when compared to the total number of jumps (9 ± 4). Utilizing a different approach (i.e., time-motion analysis), Castagna et al. (4) had previously investigated game activities and showed that high-intensity running (≥ 15.5 $km \cdot h^{-1}$) and sprinting (≥ 18.3 $km \cdot h^{-1}$) accounted for 12% and 5% of the whole match duration, respectively. Furthermore, players performed a sprint every 79 s with an average distance of 10.5 m, a duration of 1.95 s and a REC between sprints of less than 40 s (4). According to Barbero-Alvarez et al. (1), who investigated the activity profile and match demands of an OFF futsal match using a video-based system (AV Master 98 – Fast Multimedia), the distance covered during a match was 4313 ± 2139 m and the mean distance covered per minute of play was 117.3 ± 11.6 m. Moreover, the mean distances walking (0.37 – 3.6 $km \cdot h^{-1}$) and jogging (3.7 – 10.8 $km \cdot h^{-1}$) were 397 m and 1792 m, respectively, which represent 9% and 40% of the total mean distance covered. The mean distance in medium intensity activity (10.9 – 18 $km \cdot h^{-1}$) was 1232 m (i.e., 28.5% of total match), high-intensity running (18.1 - 25 $km \cdot h^{-1}$) was 571 m (13.7%) and sprinting (≥ 25.1 $km \cdot h^{-1}$) was 348 m (8.9%) (1). In a different study, PRO futsal players tracked over five matches (i.e. using DVideo software automatic tracking system) (5) were reported to cover a total distance of 3133 m (2248 interquartile ranges) for the whole match and a total relative distance of 97.9 ± 16.2 during the 1st half and 90.3 ± 12.0 $m \cdot min^{-1}$ during the 2nd. These values were somehow lower than the ones found by Castagna et al. (4), which could be explained by the fact that, in the latter study, players completed a simulated futsal match comprising four sets of 10 min, with a 5 min rest (i.e., different from an OFF game). The dissimilarities in match characteristics may have allowed players to maintain higher levels of activity due to the shorter working period.

Examining the number of sprints performed during futsal competition, Caetano et al. (3) observed, using a video automatic tracking system, that players execute 26 ± 13.3 sprints throughout the match. A more thorough analysis of the sprint demands noted that the most frequent repeated sprint actions comprised 2 consecutive sprints and a REC of ~15 s. However, sequences of 3 and 4 sprints and rest intervals of 30, 45 or 60 s have also been reported. Considering playing position, there were no differences in sprint distance covered, peak velocity, initial velocity, REC time between consecutive sprints and number of sprints per min (3). This could be explained not only by the tactical and technical characteristics of the sport (that make players more flexible to changing or rotating position) but also by the unlimited number of substitutions or the possibility of playing with a "fly goalkeeper" during match-play.

Comparing the 1st and 2nd halves, a study with Brazilian elite players (5) found that the percentage of distance covered standing and walking was higher in the 2nd half. Conversely, the distance covered at medium, high-velocity and sprinting decreased significantly when compared to the 1st half (5), which supported previous research (1, 24). A related study (7) confirmed that the total distance (1st half: 1986 ± 74.4 m; 2nd half: 1856 ± 129.7 m) and the distance covered by minute (1st half: 103.2 ± 4.4 $m \cdot min^{-1}$; 2nd half: 96.4 ± 7.5 $m \cdot min^{-1}$) decreased significantly from the 1st to the 2nd half, but found no meaningful differences regarding the number of sprints or total sprinting time. Despite these inconsistencies, it appears that intensity tends to decrease as the match approaches the final minutes which may be due not only to increased fatigue levels but also to tactical decisions (e.g., longer possessions or the utilization of a "fly goalkeeper") that "slow down" the game.

In an investigation analyzing international and national level futsal competition, Dogramaci et al. (6) reported that elite teams covered a 42% greater total distance than sub-elite (4277 ± 1030 m vs 3011 ± 999 m, respectively). Moreover, the former traveled a 58% greater jogging distance, covered a 93% higher distance while moving sideways or backwards and completed a higher total number of activities (i.e., 468 ± 77 for elite; 306 ± 81 for sub-elite) (6). Upon review of the included studies, it appears that elite futsal players perform more high-energy metabolic and mechanical activities during competition with shorter REC times. Match-related fatigue may influence high-intensity efforts and sprinting time from 1st to 2nd half. From an applied perspective, knowing the match demands, understanding the differences in performance between the two halves, and between PRO and SEMI-PRO athletes could be helpful for S&Cc and sport scientists. These data may assist in developing more adequate match-action specific training strategies, thus enhancing performance and potentially reducing the risk of injury. Interestingly, only two studies (24, 25) used wearable technology (i.e., GPS or accelerometry) during the games, highlighting the need for further research regarding the description of the external loads experienced by players during OFF competition.

5.3.2.2. Physiological Responses

Due to the frequent intermittent high-intensity actions that occur in most team-sports, researchers have long been interested in understanding the physiological stress imposed during the match by analyzing variables such as HR, VO_2 or blood lactate (La) (117-119). Particularly in futsal, eight studies (1, 4, 7, 9, 10, 25, 81, 84) have investigated the physiological responses during a match (Table 1).

Barbero-Alvarez et al. (1) monitored the HR (Polar Vantage NV) of 10 players during four competitive futsal matches. The HR_{mean} was 174 ± 7 $b \cdot min^{-1}$ (range: 164-181), which represented 90 ± 2% (range 86-93) of HR_{max}. With HR being classified based on the percentage of time spent in different zones, players spent 0.3%, 16% and 83% at intensities ≤ 65%, 85-65% and ≥ 85% of HR_{max}, respectively. Other data from OFF matches, however, displayed slightly lower HR values (86.4 ± 3.8% HR_{max}) (10). Comparing the two halves, different outcomes have been reported in the literature. On the one hand, a significant decrease in the percentage of time spent at an intensity ≥ 85% of HR_{max} was identified from 1st to 2nd half (1). On the other, no meaningful differences were found on HR_{max} (1st half: 186.9 ± 9.2 $b \cdot min^{-1}$; 2nd half: 185.7 ± 10.0 $b \cdot min^{-1}$) and HR_{mean} (1st half: 168.4 ± 12.4 $b \cdot min^{-1}$; 2nd half: 166.4 ± 12.5 $b \cdot min^{-1}$) (7). According to Castagna et al. (4), the mean HR_{max} achieved during a simulated futsal match corresponded to 90% of the maximal treadmill test values, with peak values reaching 98%. Based on these results, it appears that HR_{max} values during OFF competition are lower than the ones achieved in a simulated match (i.e., 4 ×10 min, with a 5 min intermission); however, more research is needed to clarify the differences between 1st and 2nd halves.

VO_2, a study reported that the mean game values (measured with a portable gas analyzer) were 48.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (95% confidence intervals [95% CI]: 40.1-57.1 $ml \cdot kg^{-1} \cdot min^{-1}$) and that players spent 46% of the playing time (during a simulated match) at intensities higher than 80% of VO2max (4). Moreover, the mean and peak values achieved during the modified game corresponded to 76% and 99%, respectively, of the VO_{2max} obtained in a maximal treadmill test (4). When it comes to OFF competition data, an average intensity of 79.2 ± 9.0% of VO_{2max} was achieved in terms of oxygen consumption (10). Concerning the accumulation of La, a mean la (La_{mean}) value of 5.3 (95% CI: 1.1-10.4) mmol·L^{-1} was reported after the previously mentioned simulated match investigated by Castagna et al. (4). Interestingly, and following the same pattern observed in the other variables (i.e., HR and VO_{2max}), this value was higher than OFF games, in which La_{mean} (analyzed by an electrochemical lactimeter YSI 1500) of 4.8 ± 2.3 mmol·L^{-1} (1st half) and 4.2 ± 2.2 mmol·L^{-1} (2nd half) were found (7). Conversely, Bekris et al. (9), using a portable blood analyzer, displayed higher values of La_{mean} (1st half: 14.9 ± 4.9 and 2nd half: 15.0 ± 4.7) as the assessment were performed throughout the match, when player was taken out.

The knowledge about the physiological demands of futsal is of paramount importance since it offers information concerning the stress imposed upon the players during competition. The average intensity of effort during the matches is high (mainly ≥ 85% of HR_{max}) with an important decrement of high-intensity efforts between the two halves.

5.3.2.3. Neuromuscular Responses

High-intensity efforts (e.g., sprinting, jumping, and COD) play a significant role in team-sports. Several studies indicate that stronger and more powerful players (i.e., with better-developed neuromuscular capabilities) of different sports are prone to accelerate faster, jump higher, and change direction more rapidly (120-122). Moreover, it has been shown that sport specific activities such as kicking or tackling are also influenced by the ability of an athlete to generate greater levels of force and power (123, 124). With this in mind, four studies (3, 7, 24, 82) investigated the neuromuscular outcomes during and after a futsal match.

Of note, apart from the increases in sprint time from the 1st to 2nd half discussed above, important alterations in neuromuscular function have been identified after a futsal match (3, 24). Particularly, decrements in peak force and voluntary activation (i.e., manifestations of fatigue) were present following match-play; moreover, these were significantly associated with a reduction in running actions (i.e., repeated high-intensity efforts and sprints) (7). Nevertheless, future studies are necessary to better elucidate the mechanisms (i.e., if peripheral or central in origin) impairing performance and the time-course of REC (i.e., when do values get back to pre-competition levels) following a futsal match. Therefore, coaches and strength and conditioning specialists are advised to closely monitor the training and competition load and promote post-match REC strategies to minimize injury risk and to potentially maintain players' peak neuromuscular performance throughout the season and during match-congested periods.

5.3.2.4. Biochemical Responses

To better understand the actual futsal match-play demands, and following a more holistic approach to the study of the stress imposed by competition, some researchers have investigated different biochemical markers post-game. Particularly, three studies (9, 13, 15) have focused on this topic. A biomarker associated with responses to exercise is the salivary immunoglobulin A (SlgA), and when decreased, its concentration may be a good marker of excessive training (125). Moreira et al. (15) collected unstimulated saliva samples to investigate the SIgA responses in PRO futsal players and observed a decline in absolute concentration, secretion rate, and saliva flow following a futsal match, which proposes a general risk for respiratory tract infection incidence. Hence, according to the authors' recommendations, actions should be held to minimize contact with virus or reduce TL under such conditions. Bekris et al. (9) examined the biochemical and metabolic responses as well as the muscle damage induced by futsal competition and identified increased creatine kinase (CK) levels and a reduced testosterone/cortisol ratio after the game from blood samples collected from the forearm vein.

As it could be expected, given that different positions have different demands and characteristics (85, 90), dissimilar stress levels occur in the biochemical and immune systems. Goalkeepers have been reported to have a significantly higher La concentration and IL-6 when compared to on-court players after the match; however, no differences in serum CK were obtained among positions (13). In practical terms, results from the literature suggest that futsal competition promotes a decrease of plasma SlgA, increased muscle soreness, CK levels at post and post 24 h, and different stress responses among positions. These findings should be considered by coaches, strength and conditioning professionals, and nutritionists in order to maximize athletes' performance. Useful strategies may be the utilization of different techniques to avoid overreaching in futsal players; for instance, antioxidant supplement, omega-3 fatty acid, and anti-inflammatory drug intake, as well as reducing the TL.

Table 1 Summary of time-motion analysis and physiological responses.

Study	Participants (n°)	VO_{2max}	Heart rate	Blood lactate ($mmol \cdot L^{-1}$)	Medium-intensity running	High-intensity running	Sprinting	Distance covered (m)
Barbero-Alvarez et al. (2008)	10	NR	174 ± 7 $b \cdot min^{-1}$ $90\% \pm 2^{d}$	NR	1232 m $28\% \pm 2.2^{c}$	571 m $13.7\% \pm 2.0^{c}$	348 m $8.9\% \pm 3.4^{c}$	4313 ± 2138
Bekris et al. (2020)	21	NR	$93\% \pm 2.5^{d}$	1st half: 14.86 ± 4.91 2nd half: 15.00 ± 4.67	NR	NR	NR	NR
Bueno et al. (2014)	93	NR	NR	NR	1st half: 16.4% (IQRs: $3.4)^{c}$ 2nd half: 15.4% (IQRs: $3.4)^{c}$	1st half: 8.0% (IQRs: $2.4)^{c}$ 2nd half: 7.5% (IQRs: $2.0)^{c}$	1st half: 7.6% (IQRs: $4.3)^{c}$ 2nd half: 7.2% (IQRs: $2.7)^{c}$	3133 (IQRs: 2248)
Caetano et al. (2015)	97	NR	NR	NR	NR	NR	26 ± 13.3 SP	NR
Castagna et al. (2009)	8	76% (95% CI: $59–92)^{a}$ 48.6 (95% CI: 40.1–$57.1)^{b}$ $ml \cdot kg^{-1} \cdot min^{-1}$	90% (95% CI: $84–96)^{a}$	5.3 (95% CI: 1.1–10.4)	NR	12% (95% CI: $3.8–12.9)^{c}$	5% (95% CI: $1–11.0)^{c}$	NR
Charlot et al. (2016)	10	NR	168 ± 8.6 $b \cdot min^{-1}$ $83.2\% \pm 2.3^{d}$	NR	NR	NR	NR	NR
Dogramaci and Watsford (2006)	8	NR	NR	NR	1521 ± 558 m	1105 ± 384 m	106 ± 59.9 m	4283 ± 808
Dogramaci et al. (2011)	8	NR	NR	NR	999 ± 333 m	NR	106 ± 56	4277 ± 1030
Makaje et al. (2012)	15	OF: $77.9\% \pm 9.0^{a}$ 43.7 ± 5.8^{b} $ml \cdot kg^{-1} \cdot min^{-1}$ GL: $63.2\% \pm 8.9^{a}$ 31.5 ± 4.7^{b} $ml \cdot kg^{-1} \cdot min^{-1}$	OF: 175 ± 12^{d} $b \cdot min^{-1}$ $89.8\% \pm 5.8^{d}$ GL: 147 ± 7^{d} $b \cdot min^{-1}$ $73.7\% \pm 5.1^{d}$	OF: 5.5 ± 1.4 GL: 4.2 ± 1.3	OF: 1050 ± 355 m GL: 196 ± 130 m	OF: 636 ± 248 m GL: 127 ± 85 m	OF: 422 ± 186 m GL: 110 ± 57 m	OF: 5087 ± 1104 GL: 2043 ± 702
Milanez et al. (2020)	85	NR	NR	NR	NR	NR	NR	3046 ± 1485
Milioni et al. (2016)	10	NR	1st half: 168.4 ± 12.4 $b \cdot min^{-1}$ 2nd half: 166.4 ± 12.5 $b \cdot min^{-1}$	1st half: 4.8 ± 2.3 2nd half: 4.2 ± 2.2	NR	NR	1st half: 49.5 ± 14.5 SP 2nd half: 45.5 ± 9.1 SP	1st half: 1986.6 ± 74.4 2nd half: 1856 ± 127.7
Ohmuro et al. (2020)	79	NR	NR	NR	$20\% \pm 2^{c}$	$11.3\% \pm 1.4^{c}$	$12\% \pm 3.1^{c}$	4151 ± 942^{c}
Ribeiro et al. (2020)	28	NR	NR	NR	1321.5 ± 479.8 m	675.3 ± 298.1 m	134.9 ± 54.1 m	3749 ± 1123

Study	Participants (n°)	VO_{2max}	Heart rate	Blood lactate (mmol·L^{-1})	Medium-intensity running	High-intensity running	Sprinting	Distance covered (m)
Rodrigues et al. (2011)	14	79.2% ± 9.0[a]	86.4% ± 3.8[d] 199 ± 8.5 b·min^{-1}	NR	NR	NR	NR	NR
Yiannaki et al. (2020)	16	NR	87.7% ± 4.4[d] 164.8 ± 22.3 b·min^{-1}	NR	NR	NR	NR	NR

Values expressed as mean ± SD.

[a]Mean game values with respect to maximal treadmill test values.

[b]Mean game values of VO2.

[c]Percentage of total playing time.

[d]Mean game values as percentage of maximum heart rate.

b·min−1, beats per minute; CI, confidence interval; GL, goalkeepers; IQRs, interquartile ranges; m, meters; n°, number; NR, not reported; OF, outfield player; SP, number of sprints; VO2max: aximum oxygen uptake

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5.3.3. Player Characteristics

5.3.3.1. Anthropometrics

Anthropometric characteristics (i.e., height, body mass, and body composition) are important components of physical fitness as it is well-accepted that, for example, excessive body fat can potentially impair performance in team-sports (126). Conversely, a greater percentage of muscle skeletal mass tends to increase sport performance as it contributes to energy production during high-intensity activities and enhances athletes' force production capabilities (126). In this context, several studies have investigated the anthropometric characteristics of futsal players with the database search yielding 10 articles (13, 45, 46, 51, 85-90). In general, elite futsal players have been reported to weigh, on average, ~70 kg, to measure ~1.76 m of height and to display ~15% of body fat (86, 87).

Investigations comparing elite players with their sub-elite counterparts found no significant differences in anthropometric characteristics (88, 89). For example, López-Fernández et al. (89) found similar fat mass between elite and sub-elite players. However, elite players demonstrated higher lean mass in the dominant and non-dominant legs when compared to lower-level players; moreover, the latter showed higher bilateral asymmetry in fat mass percentage. No meaningful differences were found between PRO and SEMI-PRO players in a sample of Brazilian futsal players (88). Therefore, it is still unknown to what extent height and body mass may be adequate variables to discriminate athletes from different competition levels.

Regarding playing position, research indicates significant differences on anthropometric characteristics (85, 90). In a study comparing body fat percentage among positions, P presented the highest value, followed by goalkeepers, backs, and, lastly, W (90). In contrast, a different investigation (13) found that goalkeepers were slightly taller and heavier and had a higher percentage of body fat (1.78 ± 3.2 cm, 74 ± 2.5 kg, 13 ± 2%, respectively) than D (1.74 ± 1 cm, 69 ± 2 kg, 10 ± 2%), W (1.69 ± 3 cm, 68 ± 2 kg, 11 ± 2%), and P (1.73 ± 2 cm, 71 ± 2 kg, 10 ± 2%). Similar results were found by Baroni and Leal Junior (85), who indicated that the 22 goalkeepers comprised in the study's sample were significantly heavier and taller than their 164 on-court counterparts. The lack of significant differences in body fat among on-court players could be explained by the fact that, in futsal, playing positions are highly variable during the game because of the tactical behaviors that require players to perform multiple positional demands in order to adapt to the team's tactical system. It should be highlighted, however, that it is not clear whether the higher body mass reported for goalkeepers consists of fat or muscle mass. Given the paucity of data and lack of clear reporting, further research is required to better clarify the positional differences in anthropometric characteristics of futsal players.

In summary, according to the literature, futsal players display a low percentage of fat, which seems to be commonplace among players from different playing on-court positions and different competitive levels. This information may be important to adjust training programs and should be considered on young talent detection practices.

5.3.3.2. Physiological Characteristics

The aerobic energy system has a crucial role in futsal match-play since it is well-established that this system improves REC after high-intensity exercise (127, 128). Futsal players perform around 4 km in a match, with frequent bouts of repeated sprints, ACC, and DEC with short REC times, which supports the importance of a well-developed aerobic energy system (1, 24). In addition, as reported above, players achieve mean and peak VO_2 values during competition which correspond to their 76 and 99% of VO_{2max}, respectively. Upon review, 31 studies (1, 9, 43-45, 47, 49-52, 54, 55, 77, 81, 82, 84, 85, 88, 91-105, 129) have looked at the physiological characteristics of elite futsal players (Table 2).

Considering competition level, elite and sub-elite players display dissimilar aerobic capacities (50, 81, 88, 103, 129). For example, VO_{2max} values of 62.9 ± 5.3 $ml·kg^{-1}·min^{-1}$ were reported for elite vs. 55.2 ± 5.7 $ml·kg^{-1}·min^{-1}$ for sub-elite athletes. Moreover, elite players presented a VO_2 at a ventilatory anaerobic threshold (VT_2) of 44.4 ± 4.6 $ml·kg^{-1}·min^{-1}$ while sub-elite displayed 39.1 ± 4.0 $ml·kg^{-1}·min^{-1}$ (129). Interestingly, a study found no significant differences in VO_{2max} and VO_2 at VT_2 (in an incremental test in which players used a gas analyzer) but reported that the speed at VT_2 (S_{vt2}) and speed at VO_{2max} (S_{Vo2max}) were significantly higher in elite players when compared to their sub-elite counterparts (S_{vt2}: 11.2 ± 1.0 vs. 10.0 ± 1.2 km·h^{-1}; S_{Vo2max}: 17.5 ± 0.9 vs. 15.2 ± 1.0 km·h^{-1}) (88). Similar results were found elsewhere, when comparing elite, sub-elite, and social futsal players, using the distance covered in the Futsal Intermittent Endurance Test (FIET) (50). Elite players covered a greater distance (1,378 ± 228 m) in relation to sub-elite (1,018 ± 133 m) and social players (781 ± 220 m) (50).

A detailed look at the published studies portrays that different kinds of tests have been used to assess aerobic performance in futsal (e.g., Yo-Yo IR1–IR2, FIET, 30-15 Intermittent Fitness Test, Futsal Circuit, and Carminatti's test) and that fitness field tests may be useful to evaluate the aerobic capacity on elite players (91, 92, 95-97, 99). For example, a study by Nakamura et al. (49) showed that Brazilian elite players covered 1,500 ± 287 m in the Yo-Yo IR1 test whereas a sample of under-20 players completed only 1,264.0 ± 397.9 m. Thus, it appears that such type of protocols may differentiate athletes from different age categories. A practical way to apply these field tests is through their implementation as part of the training routine as they may be equally useful for training purposes and performance monitoring. Moreover, the tests are inexpensive and need little equipment and few resources and player motivation could be increased when tests are completed with the ball.

The present findings suggest that physiological capacities may help discriminate superior-level futsal players since elite competitors display slightly higher VO_{2max} and VT_2 values and obtain superior scores in different field tests in comparison with their sub-elite counterparts. Moreover, on-court players have greater aerobic capacity when compared to goalkeepers. S&Cc and sport scientists should focus on designing training drills that favor the improvement of the aerobic capacity to prepare players to cope with the demands of match-play.

Table 2 Summary of physiological characteristics.

Study	Participants (n°)	Level	Test	Test-specific outcome	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR_{max} ($b \cdot min^{-1}$)	VT_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	Blood lactate ($mmol \cdot L^{-1}$)
Barbero-Alvarez et al. (2009)	11	Elite	TM	N/A	62.9 ± 5.3	191 ± 8	44.4 ± 4.6	12 ± 2.5
	13	Sub-Elite			55.2 ± 5.7	198 ± 13	39.1 ± 4.0	7.8 ± 1.6
Barbieri et al. (2017)	16	Elite	Futsal_circuit	N/A	NR	198.5 ± 8	NR	7.87 ± 0.7
Barcelos et al. (2017)	8	Elite	Yo-Yo IR2	764.4 ± 206.7 m	55.7 ± 2.8	184.5 ± 12.2	NR	NR
Baroni and Leal Junior (2010)	186	Elite	TM	N/A	58 ± 6.37	190.14 ± 8.42	51.25 ± 5.84	NR
Bekris et al. (2020)	21	Elite	Yo-Yo IR2	N/A	65.17	193.0 ± 8.39	NR	NR
Boullosa et al. (2013)	15	Elite	TM	N/A	57.25 ± 6.35	184 ± 5	NR	NR
	15		Yo-Yo IR1		NR	184 ± 15		8.17 ± 1.63
Castagna et al. (2009)	18	Elite	TM	N/A	65.1 ± 6.2	193 ± 2	45.2 ± 4.6	12.6 ± 2.3
	18		FIET		61.6 ± 4.6	191 ± 7	NR	12.6 ± 2.3
Charlot et al. (2016)	10	Elite	30-15 IFT	19.2 ± 0.6 km·h⁻¹	53.1 ± 2.1	NR	NR	NR
Cuadrado-Peñafiel et al. (2014)	12	Elite	TM	N/A	62.95 ± 5.21	NR	NR	NR
De Freitas et al. (2015)	10	Elite	Yo-Yo IR1	1433 ± 344[a] m	NR	198.4 ± 7.3[a]	NR	NR
De Freitas et al. (2019)	10	Elite	FIET	16.6 ± 0.3 km·h⁻¹	NR	NR	NR	NR
Farhani et al. (2019)	18	Elite	FSPT	770.2 ± 34.6W 30.08 ± 1.77 s	NR	NR	NR	NR
	18	Sub-Elite		714.5 ± 34W 35.45 ± 1.59 s				
Floriano et al. (2016)	10	Elite	TM		49.06 ± 4.7	185 ± 11	NR	8.5 ± 2.1
	10		T-CAR		51.1 ± 4.7	189 ± 9		13.6 ± 2.4
Galy et al. (2015)	22	Elite	30-15 IFT	MEL-G: 18.71 ± 1.33 km·h⁻¹ NMEL-G: 19.5 ± 0.6 km·h⁻¹	MEL-G: 51.46 ± 3.2 NMEL-G: 52.74 ± 1.94	MEL-G: 193.56 ± 8.26 NMEL-G: 187.88 ± 12.68	NR	NR
Garcia-Tabar et al. (2015)	10	Elite	SRT	N/A	NR	192 ± 5	NR	10 km·h⁻¹: 1.5 ± 0.4 12 km·h⁻¹: 2.0 ± 0.6 14 km·h⁻¹: 4.4 ± 1.2
Gorostiaga et al. (2009)	15	Elite	SRT	N/A	NR	13 km·h⁻¹: 170.7 ± 8 14 km·h⁻¹: 179.9 ± 6 15 km·h⁻¹: 183.5 ± 5	NR	13 km·h⁻¹: 4.2 ± 2.0 14 km·h⁻¹: 6.4 ± 2.1 15 km·h⁻¹: 6.2 ± 1.7

Makaje et al. (2012)	15	Elite	TM/ Yo-Yo IR2	OF: 1558 ± 451 m GL: 900 ± 403 m	OF: 60.4 ± 5.1 GL: 54.6 ± 5.7	NR	NR	NR
	15	Sub-Elite		OF: 1203 ± 660 m GL: 726 ± 316 m	OF: 57.2 ± 6.2 GL: 52.4 ± 3.5			
Milanez et al. (2011)	9	Elite	TM	N/A	59.6 ± 2.5	190.4 ± 6.4	42.2 ± 6.0	NR
Miloski et al. (2014)	12	Elite	Yo-Yo IR2	450 ± 95.2[a] m	48.6 ± 3.9[a]	NR	NR	NR
Miloski et al. (2016)	12	Elite	MSRT	N/A	49.5 ± 3.5[a]	NR	NR	NR
Nakamura et al. (2016)	18	Elite	Yo-Yo IR1	1506.7 ± 287.1 m	NR	NR	NR	NR
Nakamura et al. (2018)	11	Elite	Yo-Yo IR1	1160 ± 472.61 m	NR	NR	NR	NR
Naser and Ali (2016)	8	Elite	FIET	1378 ± 228.1 m	NR	NR	NR	NR
	8	Sub-Elite		1018.1 ± 133.8 m				
Nikolaidis et al. (2019)	16	Elite	MSRT	10:20 ± 1:20 min	NR	192.2 ± 6.9	NR	NR
Nogueira et al. (2018)	15	Elite	Yo-Yo IR2	573.3 ± 193.4[a] m	NR	NR	NR	NR
Oliveira et al. (2013)	15	Elite	Yo-Yo IR1	1244 ± 298[a] m	NR	NR	NR	NR
Pedro et al. (2013)	9	Elite	TM		63.7 ± 4.1	189 ± 7	43.0 ± 4.1	NR
	11	Sub-Elite	TM	N/A	62.1 ± 4.4	204 ± 11	44.0 ± 3.8	
Soares-Caldeira et al. (2014)	6	Elite	Yo-Yo IR1	1280 ± 363[a] m	NR	NR	NR	NR
	7	Elite		1291 ± 363[a] m				
Teixeira et al. (2019)	28	Elite	FIET	15.89 ± 1 km·h^{-1}	NR	NR	NR	NR
Valladares-Rodriguez et al. (2017)	13	Elite	30-15 IFT	20.2 ± 1.7 km·h^{-1}	NR	189 ± 7	NR	NR
Wlodarczyk et al. (2019)	12	Elite	TM	N/A	57.53 ± 1.1	187.50 ± 10	38.45 ± 3.9	10.9 ± 1.2
Wlodarczyk et al. (2020)	12	Elite	TM	N/A	56.14 ± 3.1[a]	187.09 ± 10.3[a]	37.69 ± 4.2[a]	11 ± 2.1[a]
Zarebska et al. (2018)	14	Elite	TM	N/A	56.66 ± 2.62	187 ± 10	NR	11.4 ± 2
Zarebska et al. (2019)	11	Elite	TM	N/A	55.81 ± 3.94[a]	192.7 ± 7[a]	NR	11.6 ± 2.2[a]

Values expressed as mean ± SD.

[a]Pre-intervention values.

[b]·min−1, beats per minute;

FIET, futsal intermittent endurance test; FSPT, futsal special performance test; GL, goalkeeper; HRmax , maximum heart rate; MSRT, multistage 20 m shuttle-run test; MEL-G, Melanesians group; NMEL-G, non-Melanesians group; n°, number; N/A, not applicable; NR, not reported; OF, outfield players; SRT, submaximal running test; T-CAR, Carminattis's test; TM, treadmill test; VO2max , maximum oxygen uptake; VT2, ventilator anaerobic threshold; Yo-Yo IR1, Yo-Yo intermittent recovery test level 1; Yo- Yo IR2, Yo- Yo intermittent recovery test level.

5.3.3.3. Neuromuscular Characteristics

5.3.3.3.1. Strength capability.

Strength and power capabilities are key components in most team-sports. Several studies have presented that stronger and more powerful players of different modalities tend to be faster, have better COD ability, and jump higher (120, 121, 130). In this context, four studies (43, 53, 108, 109) investigated the strength capabilities of futsal players (Table 3). Utilizing an isokinetic dynamometer, different authors (53, 108, 109) assessed elite futsal players' strength levels by reporting peak torque values of the quadriceps and hamstrings. De Lira et al. (109) reported that peak torque values at $60^{\circ}\cdot s^{-1}$ of the dominant leg were 223.9 ± 33.4 N·m for the quadriceps and 128 ± 27.6 N·m for the hamstrings, while the non-dominant leg displayed values of 224 ± 35.8 N·m and 124.1 ± 20.1 $N\cdot m^{-1}$ for the knee extensors and flexors, respectively. The H/Q ratio was 0.58 ± 0.1. Interestingly, when the mixed H/Q ratio (i.e., hamstrings ECC angular velocity of $30^{\circ}\cdot s^{-1}$ and quadriceps CON velocity of $240^{\circ}\cdot s^{-1}$) was assessed in the preferred and non-preferred limbs of 40 players, significant contralateral differences were found on knee flexors' ECC contractions and in the H/Q ratio in favor of the preferred limb (53). Only one study assessed the one repetition-maximum (1RM) on the half-squat exercise in order to characterize futsal players' strength qualities (1RM: 94.73 ± 17.01 kg) (43).

Considering the previous, more research is clearly needed to investigate the force production capabilities of futsal athletes, as the vast majority of research utilized isokinetic dynamometry. Accordingly, the dominant leg seems to be stronger (i.e., reach higher peak torque values) than the non-dominant leg. Based on this information, strength and conditioning specialists should be aware that unilateral strength testing may be necessary to allow preparing specialized and tailored training plans to maximize lower-body strength and attenuate the likelihood of injuries. However, given that isokinetic testing is extremely time-consuming, expensive, and not practical to use in real world scenarios, other exercises (e.g., half-squat, split squat, hip-thrust, or deadlift, isometric tests) should be implemented when assessing lower-body strength.

5.3.3.3.2. Jumping ability

Data from futsal competition indicates that players perform multiple high-intensity efforts (i.e., jumping, sprinting, or COD) (3, 24). For that reason, and considering that lower-body powerful actions are determinant during the match, several researchers have investigated power related capacities of futsal players. Particularly, 14 studies (43-56) assessed elite futsal players' jumping ability (Table 3). For example, an investigation with 63 PRO players reported jump heights (measured with a contact mat) of 37.8 cm in the squat jump and 38.5 cm in the CMJ as well as bar mean propulsive and peak power outputs of 9.2 and 20.4 $W \cdot kg^{-1}$, respectively (56). Similar values for the CMJ were reported elsewhere (47).

Considering the different levels of futsal players, Naser and Ali, (50) identified no significant differences in CMJ_{height} between elite and sub-elite futsal players. Despite the need for players to execute vertical jump actions during futsal competition, it seems that these may be less determinant for performance when compared to other sports, such as soccer. Based on the studies that have assessed vertical jump height, it appears that elite futsal players do not display greater jumping ability than their sub-elite counterparts, potentially due to the limited influence of jumping ability in the game. However, it has been shown that the successful application of vertical ground reaction forces (i.e., as in vertical jumping) may play a significant role in multiple athletic actions (e.g., sprinting or COD) (41). For this reason, S&Cc are encouraged to include multiple bilateral and unilateral jumping tasks in their training programs to maximize lower-body power and, consequently, performance of elite futsal players.

5.3.3.3.3. Sprinting ability

Data from match demands demonstrates that futsal players perform ~26 sprints with an average duration of 2–4 s over 8–20 m (3). Considering that, several authors (44, 45, 47-51, 55, 56, 84, 106, 107, 110, 111) investigated the sprint performance of futsal players (Table 3). Loturco et al. (56) utilized photocells to examine sprint capabilities and found velocities (i.e., average velocity derived from time and distance) of 4.81 ± 0.25 $m \cdot s^{-1}$ (5 m), 5.68 ± 0.19 $m \cdot s^{-1}$ (10 m), and 6.61 ± 0.22 $m \cdot s^{-1}$ (20 m) in elite futsal players. Regarding ACC ability (i.e., calculated as the rate of change of velocity with respect to time), the same study reported values of 4.64 ± 0.50 $m \cdot s^{-2}$ for 0–5 m, 1.22 ± 0.22 $m \cdot s^{-2}$ for 5–10 m, and 0.74 ± 0.09 $m \cdot s^{-2}$ for 10–20 m. Gorostiaga et al. (47) assessed 5 and 15 m sprint times (not velocities) of 15 players (using photocell gates) and found values of 1.01 ± 0.02 and 2.41 ± 0.08 s, respectively.

Regarding competition level, a training approach based on the force–velocity profile found that 1st Division futsal players sprinted 5 m in 1.36 ± 0.04 s and 20 m in 3.36 ± 0.09 s while 2nd Division players demonstrated lower sprint performances (5 m: 1.40 ± 0.02 s; and 20 m: 3.46 ± 0.04 s) (107). Along the same lines, other studies (50, 106) observed that elite futsal players run faster over 5, 10, and 20 m than sub-elite or social players.

From the above information, it appears that elite players tend to display higher sprinting ability when compared to their sub-elite peers, although further research is necessary. Nevertheless, given that the majority of the published literature indicates that higher-level players tend to be faster, short sprints should be seen as an important training stimulus that may enhance the players' ability to succeed at superior competition levels, where match demands are greater.

5.3.3.3.4. Change of direction ability and agility

COD is one of most important efforts in futsal due to the rapid changes of activity during the match. COD relies on a series of anthropometric (e.g., height, leg length), physical (e.g., lower-body and trunk muscular strength, speed-power-related capabilities), and technical aspects (e.g., stride adjustments, foot placement) (131, 132). In this context, six investigations (45, 48, 49, 56, 106, 111) have performed an in-depth analysis of this paramount ability in futsal players (Table 3). In a study that examined COD performance on different sports, including futsal, players performed a zig-zag test consisting of four 5 m sections marked with cones set at 100◦ angles. The results found that futsal players obtained a COD velocity of 3.52 ± 0.11 $m{\cdot}s^{-1}$ (56). When a complementary investigation from the same research group assessed the "COD deficit" (i.e., the difference in velocity between a linear sprint and a COD task of equivalent distance) for the first time in futsal, players from this modality were found to be more efficient than soccer players at changing direction but displayed COD deficits similar to other team-sports (i.e., rugby and handball players) (111). Of note, a unique investigation (106) designed a "Y" -shaped pattern test to evaluate COD and agility in futsal with and without ball using a timing gate system. The COD and agility assessments without the ball requested participants to touch the ball and change direction; with ball, players had to dribble and conduct the ball during the execution of each test. In the COD test, participants had advanced knowledge of the task and knew which cone would light up. In contrast, the agility drill was not planned, and players needed to identify a stimulus and react accordingly. The results demonstrated that both tests were reliable after trials of submaximal intensity, with lower reliability of the non-dominant leg (106).

In summary, further investigations regarding COD ability are needed in futsal. S&Cc should implement COD training during tactical–technical sessions or develop ACC-DEC capabilities through the use of other training approaches (i.e., resisted sprints, horizontally oriented power exercises, or ECC training) given the importance of COD maneuvers in futsal.

Table 3 Summary of neuromuscular characteristics.

Study	Participants (n°)	Level	Strength	Jump (cm)	Sprint	COD (°)
Charlot et al. (2016)	10	Elite	NR	NR	5 m: 1.00 ± 0.07 s 10 m: 1.72 ± 0.07 s 15 m: 2.38 ± 0.05 s 30 m: 4.20 ± 0.11 s	NR
Cuadrado-Peñafiel et al. (2014)	12	Elite	1RM Squat: 94.73 ± 17.01 kg	CMJ: 35.9 ± 5.29	NR	NR
De Freitas et al. (2019)	10	Elite	NR	SJ: 34.6 ± 3.9[a] CMJ: 36.6 ± 4.1 [a]	15 m: 2.43 ± 0.12[a] s	NR
De Lira et al. (2017)	30	Sub-Elite	60°·s⁻¹ (N·m) Ext Dom: 223.9 ± 33.4 Ext N-Dom: 224 ± 35.8 Flex Dom: 128 ± 27.6 Flex N-Dom: 124.1 ± 20.1	NR	NR	NR
Galy et al. (2015)	22	Elite	NR	MEL-G: CMJ: 50.44 ± 5.88 NMEL-G: CMJ: 45.16 ± 4.34	MEL-G: 5 m: 1.41 ± 0.11 s 10 m: 2.18 ± 0.12 s 15 m: 2.82 ± 0.15 s 30 m: 4.72 ± 0.17 s NMEL-G: 5 m: 1.35 ± 0.08 s 10 m: 2.13 ± 0.13 s 15 m: 2.84 ± 0.12 s 30 m: 4.80 ± 0.15 s	T-Test (90/180°): MEL-G: 10.47 ± 0.58 s NMEL-G: 11.01 ± 0.64 s
Gomes et al. (2011)	92	Elite	NR	SJ: 36.74 ± 4.28 37.42 ± 4.86 36.61 ± 5.28 CMJ: 38.88 ± 4 39.72± 5.08 38.48 ± 4.80	NR	NR
Gorostiaga et al. (2009)	15	Elite	NR	CMJ: 38.1 ± 4.1	5 m: 1.01 ± 0.02 s 15 m: 2.41 ± 0.08 s	NR

Jiménez-Reyes et al. (2019)	39	Elite	NR	NR	5 m: 1.36 ± 0.04 s 20 m: 3.36 ± 0.09 s	NR
	10	Sub-Elite			5 m: 1.40 ± 0.02 s 20 m: 3.46 ± 0.04 s	
Loturco et al. (2018)	63	Elite	NR	SJ: 37.82 ± 7.10 CMJ: 38.50 ± 4.88	5 m: 4.81 ± 0.25 m·s^{-1} 10 m: 5.68 ± 0.19 m·s^{-1} 20 m: 6.61 ± 0.22 m·s^{-1}	Zig-zag (100°): 3.52 ± 0.11 m·s^{-1}
Loturco et al. (2020)	62	Elite	NR	NR	5 m: 4.79 ± 0.22 m·s^{-1} 10 m: 5.67 ± 0.23 m·s^{-1} 20 m: 6.62 ± 0.25 m·s^{-1}	Zig-zag (100°): 3.52 ± 0.16 m·s^{-1}
						COD-Def zig-zag (100°): 3.09 ± 0.25 m·s^{-1}
Miloski et al. (2016)	12	Elite	NR	CMJ: 47.5 ± 5.5[a]	5 m: 1.10 ± 0.08[a] s 20 m: 3.14 ± 0.11[a] s	T-Test 90/180°: 9.24 ± 0.31[a] s
Nakamura et al. (2016)	18	Elite	NR	SJ: 37.75 ± 3.93 CMJ: 39.22 ± 4.42	5 m: 1.05 ± 0.04 s 10 m: 1.78 ± 0.06 s 20 m: 3.05 ± 0.10 s	Zig-zag (100°): 5.71 ± 0.22 s
Naser and Ali (2016)	8	Elite	NR	CMJ: 52.1 ± 4.2	5 m: 1.00 ± 0.04 s 10 m: 1.75 ± 0.03 s 20 m: 2.99 ± 0.04 s	NR
	8	Sub-Elite		CMJ: 49.9 ± 3.9	5 m: 1.06 ± 0.02 s 10 m: 1.78 ± 0.01 s 20 m: 3.05 ± 0.04 s	
Nikolaidis et al. (2019)	16	Elite	NR	ABK: 38.9 ± 6.1	10 m: 1.85 ± 0.12 s 20 m: 3.18 ± 0.17 s	NR
Nogueira et al. (2018)	15	Elite	NR	SJ: 36.31 ± 4.08[a] CMJ: 40.11 ± 4.73[a] DJ: 38.33 ± 4.75[a]	NR	NR

Nunes et al. (2018)	40	Elite	$60^{\circ}\cdot s^{-1}$ (N·m) $240^{\circ}\cdot s^{-1}$ (N·m) $30^{\circ}\cdot s^{-1}$ Ecc (N·m) $120^{\circ}\cdot s^{-1}$ Ecc (N·m)	Ext Pref: 214.7 ± 49.6 Ext N-Pref: 216.5 ± 51.6 Flex Pref: 136.6 ± 31.7 Flex N-Pref: 135.8 ± 3 Ext Pref: 178.1 ± 53.16 Ext N-Pref: 176.8 ± 52 Flex Pref: 124.3 ± 40.3 Flex N-Pref: 115.9 ± 38.1 Ext Pref: 296 ± 75.7 Ext N-Pref: 277.2 ± 73 Flex Pref: 173.5 ± 35.8 Flex N-Pref: 162.9 ± 40.8 Ext Pref: 299.3 ± 66.4 Ext N-Pref: 277.3 ± 66.1 Flex Pref: 185.7 ± 35.8 Flex N-Pref: 172.7 ± 58	NR	NR	NR
Nunes et al. (2020)	20	Elite	NR		SJ: 36.6 ± 3.2[a] 35.7 ±3.6[a] CMJ: 39.4 ± 3.4[a] 38.6 ± 3.9	5 m: 1.07 ± 0.04[a] s 1.06 ± 0.05[a] s 10 m: 1.39 ± 0.04[a] s 1.37 ± 0.05[a] s 15 m: 2.52 ± 0.06[a] s 2.52 ± 0.10[a] s	NR
Sekulic et al. (2019)	12	Elite	NR		NR	10 m: 1.63 ± 0.07 s	CODS_DD (38°): 2.39 ± 0.19 s CODS_DND 38°): 2.57 ± 0.16 s CODS_TD 38°): 2.03 ± 0.11 s COD_TND 38°): 2.31 ± 0.12 s

	20	Sub-Elite				10 m: 1.69 ± 0.11 s	CODS_DD (38°): 2.57 ± 0.22 s CODS_DND 38°): 2.65 ± 0.15 s CODS_TD 38°): 2.08 ± 0.14 s COD_TND 38°): 2.23 ± 0.10 s
Soares-Caldeira et al. (2014)	6	Elite		NR	SJ: 33.13 ± 5.76 CMJ: 38.82 ± 6.39	NR	NR
	7	Elite			SJ: 34.47 ± 2.50 CMJ: 42.77 ± 2.78		
Teixeira et al. (2019)	28	Elite		NR	SJ: 34.42 ± 4.15[a] CMJ: 35.37 ± 3.65 [a]	5 m: 4.75 ± 0.46[a] $m \cdot s^{-1}$ 15 m: 6.21 ± 0.37[a] $m \cdot s^{-1}$	NR
Vieira et al. (2016)	17	Elite	$60° \cdot s^{-1}$ (N·m)	Ext Dom: 253.31 ± 33.81 Ext N-Dom: 244.83 ± 24.78	NR	NR	NR
			$180° \cdot s^{-1}$ (N·m)	Ext Dom: 184.04 ± 18.84 Ext N-Dom: 182.86 ± 20.17			
			$300° \cdot s^{-1}$ (N·m)	Ext Dom: 138.59 ± 17.27 Ext N-Dom: 142.33 ± 18.77			

Values expressed as mean ± SD.

[a]Pre-intervention values.

ABK, Abalakov jump test; cm, centimeter; CMJ, countermovement jump test; COD, change of direction; COD-Def, change of direction Deficit; CODS_DD, change of direction dominant leg with ball; CODS_DND, change of direction of non-dominant leg with ball; CODS_TD, change of direction of dominant leg without ball; CODS_TND, change of direction of nondominant leg without ball; Dom, dominant leg; Ecc, eccentric; Ext, extensor; Flex, flexor; HJ, horizontal jump test; L, left leg; MEL-G, Melanesians group; NMEL-G, non-Melanesians group; n°, number; N-Dom, non-dominant leg; N-Pref, non-preferred leg; NR, not reported; Pref, preferred leg; R, right leg; s, seconds

5.4. LIMITATIONS

Some limitations should be addressed when considering the present research. Firstly, the number of studies assessing each variable is quite different, which means that the evidence level is dissimilar among variables. For example, there are more studies describing the match-play demands via time–motion analysis than describing the strength or COD capacities of futsal players. Secondly, the instruments, tests, or data collection procedures differed among studies, which precluded a direct comparison and interpretation of the data in some occasions. Further studies are still necessary to have a clearer picture of the futsal match-play demands, particularly, using new technologies (e.g., GPS or accelerometry-based). In addition, more research into the athletes' physical characteristics and performance outcomes (and how they fluctuate across a competitive season) would bring further understanding on the neuromuscular profile of futsal players.

5.5. CONCLUSIONS AND PRACTICAL APPLICATIONS

This systematic review provides useful information for S&Cc and sport scientists regarding the match demands, anthropometric characteristics, and physical qualities of elite and sub-elite male futsal players. The results indicated that futsal is characterized by intermittent high intensity activities with a great number of ACC, DEC, and sprints; short REC times between them; and multiple COD actions during match-play. The abundance of these types of efforts produces important decrements in physiological and neuromuscular responses between the two halves and immediately following match-play. Moreover, biochemical responses appear to be affected up to 24 h after the match. Comparing competition level, differences were observed in match demands, with elite players covering higher distance, performing more high-intensity actions, and presenting lower standing time when compared to sub-elite players. An analysis of the anthropometric characteristics of futsal players showed low percentages of body fat with no differences between on-court players of different positions or level of competition. However, goalkeepers were found to present higher body fat. Regarding the physiological characteristics of futsal players, these display VO_{2max} values of around 62 $ml \cdot kg^{-1} \cdot min^{-1}$. Elite futsal players possess higher VO_{2max}, when compared to their sub-elite counterparts. From the present review, it can be concluded that further investigation on the neuromuscular capabilities (i.e., strength, jumping, and COD) of futsal players is warranted. Still, it appears that elite futsal players present better sprinting abilities when compared to lower-level players but that jumping capacity seems not to differentiate between competition levels. Futsal players aiming to compete at the highest level should focus on developing maximal speed, lower-body power and strength, aerobic capacity, and lean muscle mass.

VI – STUDY 2

VI. STUDY 2

LOAD MONITORING, STRENGTH TRAINING, AND RECOVERY IN FUTSAL: PRACTITIONERS' PERSPECTIVES

6.1. INTRODUCTION

Futsal is a high-intensity intermittent sport, in which players are exposed to considerable physiological, neuromuscular, and biochemical stress during the game (61). Match-play data indicate that futsal players cover a total distance of ~4000 m, of which ~675 m were spent running (12 – 18 $km \cdot h^{-1}$) and ~130 m sprinting (>18 $km \cdot h^{-1}$), perform ~70 ACC_{HI} and DEC_{HI} and complete ~170 COD (24, 133). In addition, a recent study (62) reported that, during a training microcyle, elite futsal players may encounter very high demanding scenarios in terms of locomotor and velocity metrics, reaching values similar to those observed in match-play. As such, not only competition load, but also the load players experience in training should be closely monitored.

S&Cc use TL as an essential tool to prepare tailor-made training plans and control the volume and intensity of the training sessions (134). The consensus statement of the International Olympic Committee on load in sports and risk of injury states that a successful TL monitoring system is fundamental to ensure the adaptation to stress, maximize physical performance, and possibly minimize the risk of injury (135). The load could be considered as either internal, defined as the physiological or psychological stress imposed on the athlete (i.e., RPE, HR), or external, the objectively measured work performed (e.g., distance covered, number of ACC or running speed) (136). Both internal and external load metrics are commonly used for managing the TL in team-sports (136, 137). However, when it comes to futsal, it is unclear which methods are the most utilized by current S&Cc from PRO teams to monitor the TL and player's physical capacities over the season.

Another important strategy commonly used by S&Cc to reduce injuries in sports (138, 139) and enhance physical performance (140) is ST, due to its well documented benefits. For example, Case et al., (141) found that maximum Pre_{se} relative back squat strength differed between injured and uninjured male (i.e., football) and female athletes (i.e., softball and volleyball), with significantly lower values found in athletes that sustained an injury during the season. Rønnestad et al. (142) observed that a weekly ST was enough to maintain strength, sprint, and jump ability during the competitive season, whereas completing only one ST session every second week, resulted in a reduction in strength and 40 m sprint performance in PRO soccer players. In futsal, Torres-Torrelo et al. (143) concluded that a light load and low volume ST performed twice a week (as a complement to specific futsal training) led to improvements in physical performance, further supporting the importance of training for strength development during the season. Still, to date, little is known concerning ST and its characteristics (i.e., session duration, frequency, and exercise prescription) during normal (e.g., one game/week) and congested (e.g., two or more games/week) weeks in futsal. Thus, understanding the ST practices from PRO S&Cc may provide important information to other practitioners regarding the training characteristics, methods, and programming strategies being currently used in real-world scenarios.

Futsal competition, as shown in different studies (61, 144), produces significant post-match acute and residual physiological, neuromuscular, and biochemical alterations. Neuromuscular capabilities (e.g., peak force) and biochemical variables (e.g., CK and testosterone/cortisol ratio) may change significantly following match-play (7, 9), despite the fact that, in futsal, the number of substitutions is unlimited. Hence, REC plays a crucial role when preparing players to cope with the stress they are submitted to during the competitive season. In team-sports, REC methods can be focused on physiological (i.e., active REC, rest, and sleep), physical (i.e., water immersion, contrast therapy, stretching, massage), psychological, and nutritional (i.e., supplements, nutrition) aspects (145). Nevertheless, literature on the REC strategies used in futsal is scarce, especially in terms of the methods employed, its frequency and duration, and the different practices according to game location (i.e., "home" or "away") (144).

Considering that futsal is an emerging team-sport, and that there is still a paucity of research on several important topics (e.g., TL and fatigue monitoring, physical preparation, and REC), characterizing the way S&Cc work in real-world contexts is of interest. This valuable information may allow determining the current strengths, weaknesses, and opportunities for improvement to further develop futsal science and practice. Therefore, the present qualitative study aimed at describing the practices of futsal S&Cc considering: 1) the TL monitoring and player's physical capacities evaluation practices across the season; 2) the characteristics and prescription of ST during normal and congested weeks; and 3) the REC strategies and methods following "home" or "away" games. There was no leading hypothesis, and the questionnaire was designed to answer the three main research questions declared above.

6.2. METHODS

6.2.1. Study Design

An exploratory study was designed to provide descriptive information about TL monitoring, players' performance and fatigue assessment practices, and ST and REC strategies in PRO futsal. Data was collected from S&Cc working in Spain and Portugal.

6.2.2. Participants

Thirty-seven male S&Cc (age range: 20 – >50 years; PRO experience range: 1 – >8 years), working in the 1st, 2nd, or 2nd B divisions from Spain (n = 24) and Portugal (n = 13) volunteered to take part in the study. According to the inclusion criteria S&Cc should: a) work in the men´s 1st, 2nd, or 2nd B divisions and women´s 1st division; and b) answer all the questions of the survey successfully. Data was excluded if S&Cc: a) did not work in the above-mentioned divisions or worked exclusively within the club's academy (i.e., youth categories); and b) did not complete the survey or completed it only partially. All participants were informed of the benefits and risks of participating, and informed consent was obtained before undertaking the questionnaire, with the approval of Local Ethics Committee with the registration number CE072008.

6.2.3. Procedures

All S&Cc were contacted electronically to introduce the study and present the informed consent needed to participate in the anonymous online survey. The questionnaire, adapted from previous research (146-149) and developed using Google Forms, was sent by email with a web link created with the mentioned platform. The data were collected from February 2021 to April 2021. Responses were screened to determine potential duplicates and questionable answers, such as untruthful, unrealistic, or unfinished responses. The survey consisted of four sections: a) background information (4 questions); b) TL monitoring and assessment of players´ performance and fatigue (5 questions); c) ST practices (13 questions); and d) REC methods (6 questions). All questions (n = 28) were closed, providing respondents with a predetermined set of answers that included a comment box "other" in the majority of them. Most questions allowed more than one response because coaches could report using multiple methods. Hence, some questions had more responses than others. Pilot testing of the survey was conducted by all the authors, then by two practitioners (S&Cc) to avoid ambiguity of terms and ensure its validity for use with this population.

6.2.4. Stastistical Analysis

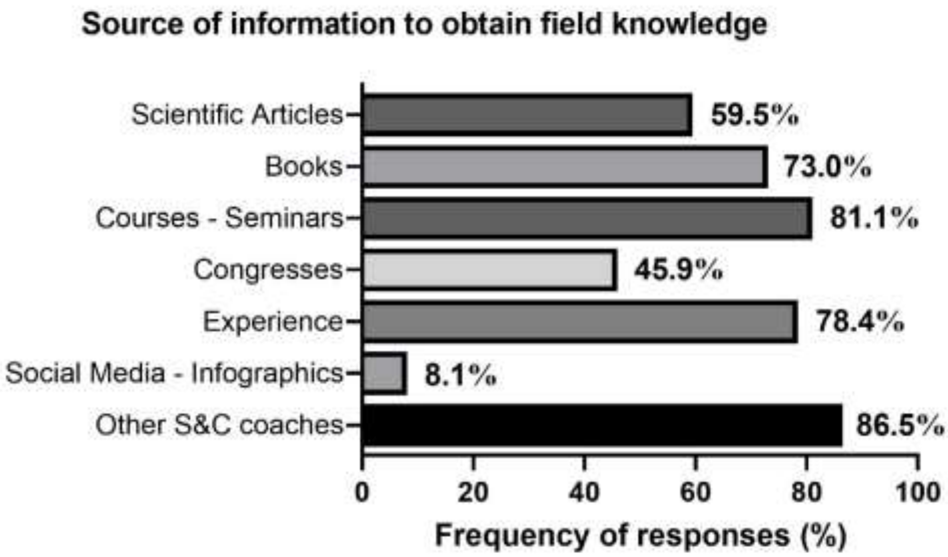
Statistical analysis was performed using the Jamovi Statistical package (2020; version 1:8). Responses were analyzed using frequency analysis for each question and presented as absolute frequencies and percentages. Mean ± standard deviation (SD) was calculated for a single question: "The importance of strength in futsal" as a 1 – 5 Likert scale (1 = not very important, 5 = extremely important) was used. Thematic analysis was conducted according to Braun and Clarkes´ guidelines (150), previously used in sport science surveys (147, 151), with the following 6 phases: a) familiarization with the data; b) generating initial codes; c) searching for themes; d) reviewing themes; e) defining and naming themes; and f) producing the report.

6.3. RESULTS

Coaches' Background Information

Thirty-seven coaches completed the survey. From the total sample, 76.6% (n = 25) reported working in their respective country's men´s 1st Division, 5.4% (n = 2) 2nd Division, 10.8% (n = 4) 2nd B Division, and 16.2% (n = 6) indicated coaching in women´s 1st Division. Regarding age, 35.1% of the practitioners were 30 – 39 years old, 29.7% were 20 – 29 years old, 24.3% were 40 – 49, and 10.8% were >50 years old. Considering coaching experience, 43.2% of S&Cc declared working in futsal >8 years, 35.1% between 4 – 7 years, 13.5% between 1 – 3 years, and 8.1% had only one year of experience. Finally, when answering the question "From what type of sources do you obtain information related to your area of expertise?" the three most frequent responses were "Other S&C coach" (86.5%), "Courses-Seminars" (81.1%) and "Experience" (78.4%), as shown in Figure 2.

Figure 2 The percentage of the respondents answering what type of resources use to obtain information about their field of knowledge.

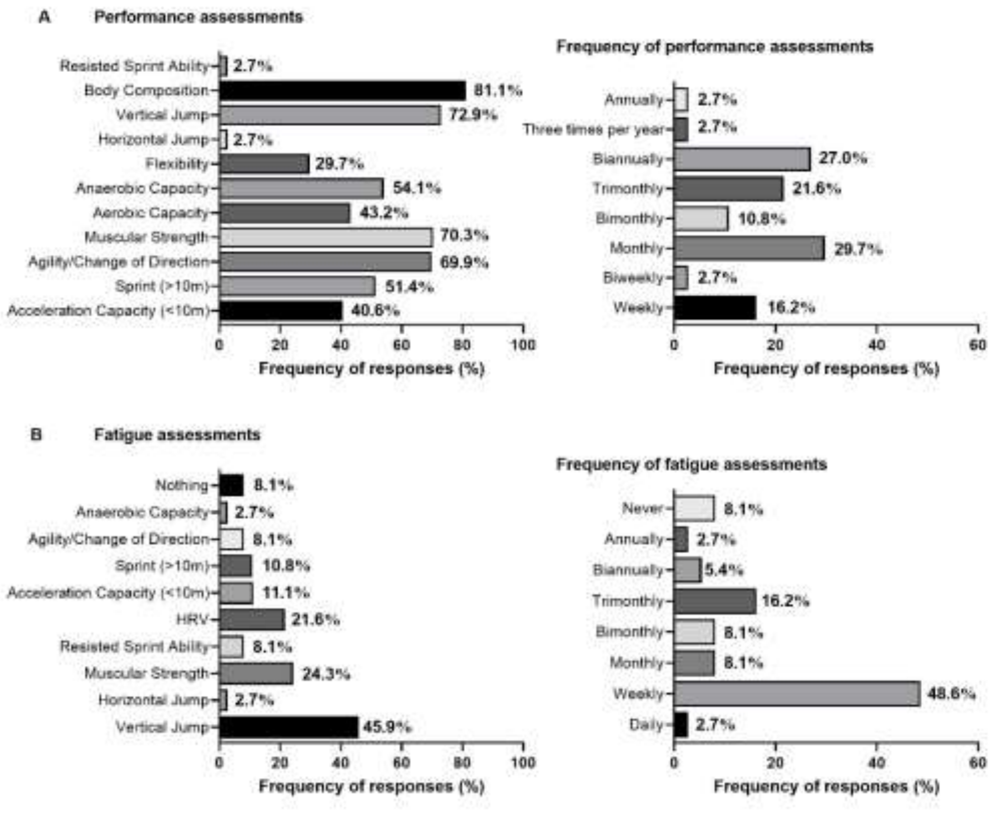


S&C: strength & conditioning

Monitoring Practices

Figure 3 outlines the tests and time-periods used for player's performance and fatigue evaluation during the season. S&Cc reported assessing body composition (81.1%), vertical jump ability (72.9%), muscular strength (70.3%), COD-agility (69.9%), anaerobic capacity (54.1%) sprint (>10m) (51.4%), aerobic capacity (43.2%), ACC ability (<10m) (40.6%), and flexibility (27.0%), in testing sessions organized on a monthly (29.7%), biannually (27.0%), trimonthly (21.6%), weekly (16.2%) or bimonthly (10.8%) basis. Regarding player's fatigue, vertical jump ability (45.9%), muscular strength (24.3%), and HR variability (21.6%) were commonly used, being tested weekly (48.6%), trimonthly (16.2%), monthly (8.1%) or bimonthly (8.1%). The most common method for recording TL was RPE (86.5%) followed by external workload monitoring with wearable tracking system (GPS/accelerometer) (37.8%), HR (40.5%), Acute-Chronic Workload ratio (37.8%), and Total Quality Recovery Scale – Wellness (10.8%). Only one (2.7%) S&Cc reported not monitoring TL.

Figure 3 **A)** The percentage of the respondents answering the tests, and time-interval for player's performance assessment. **B)** The percentage of the respondents answering the tests and time-interval of player's fatigue assessment.

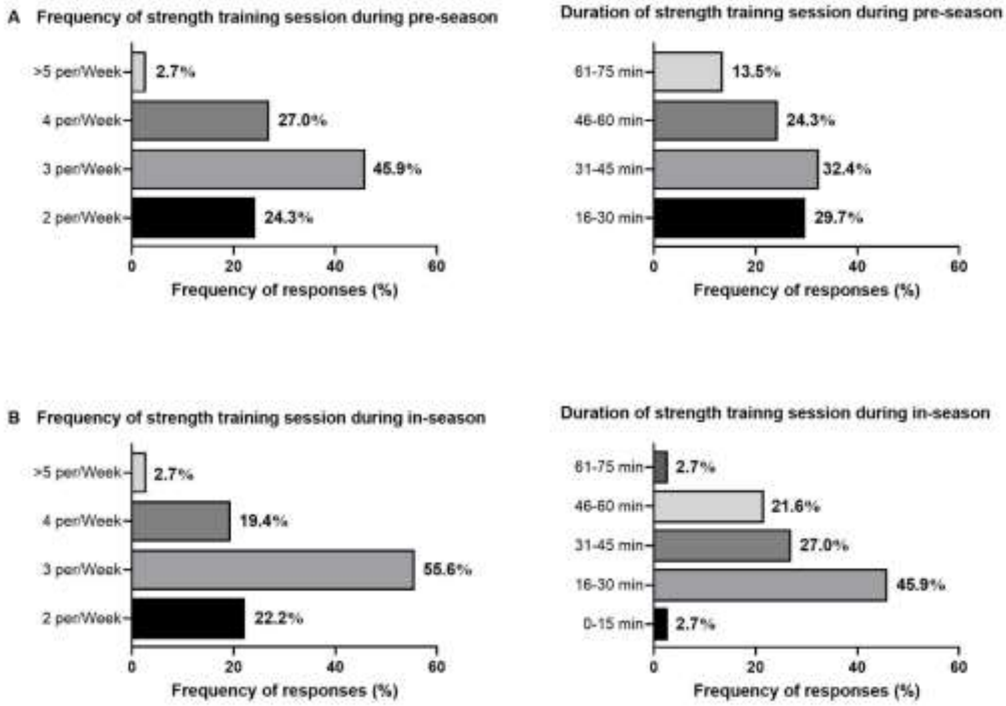


Strength Training

Figure 4 depicts the frequency and the duration of ST during Pre_{se} and In_{se}. Overall, ST was considered as "extremely important" (4.8 ± 0.4) in futsal. During normal weeks, S&Cc reported completing the first ST on the morning of Match-day (MD) +2 (43.2%), followed by the afternoon of MD+1 (16.2%) or morning of MD+3 (16.2%), and afternoon of MD+3 (13.5%). Most ST sessions were reported to last 16 – 30 min (45.9%), followed by 31 – 45 min (29.7%), 46 – 60 min (16.2%), 0 – 15 min (2.7%), 61 – 75 min (2.7%), and >76 min (2.7%), and focused on full-body training (i.e., upper and lower limbs) (73.0%) and core (67.6%) exercises. During congested periods, 18.9% of the S&Cc reported not prescribing ST. Amongst those who do, most indicated that ST is performed in the morning of MD+2 (27.9%), afternoon of MD+1 (16.2%) or MD+2 (16.2%), morning of MD+1 (10.8%), and morning or afternoon of MD+3 (2.7%). In congested periods, ST sessions last between 16 – 30 min (45.9%), 0 – 15 min (24.3%), 31 – 45 min (18.9%), 46 – 60 min (8.1%), and 61 – 75 min (2.7%). The training session is centered on core (62.2%) and full-body (45.9%) exercises.

Concerning ST prescription, the most used method reported was %1RM – XRM (59.5%), followed by velocity-based training (21.7%), repetitions in reserve (18.9%), until failure (10.8%), and circuit training (2.7%). Finally, the main aspects to improve related to ST, as reported by the S&Cc were: "Better Monitoring" (73.5%), "More Individualized" (62.2%), "Better Facilities" (55.6%), "More Staff" (35.1%) and "More Time" (10.8%).

Figure 4 **A)** The percentage of the respondents answering the frequency and time range of the strength training during the pre-season. **B)** The percentage of the respondents answering the frequency and time range of the strength training during the in-season



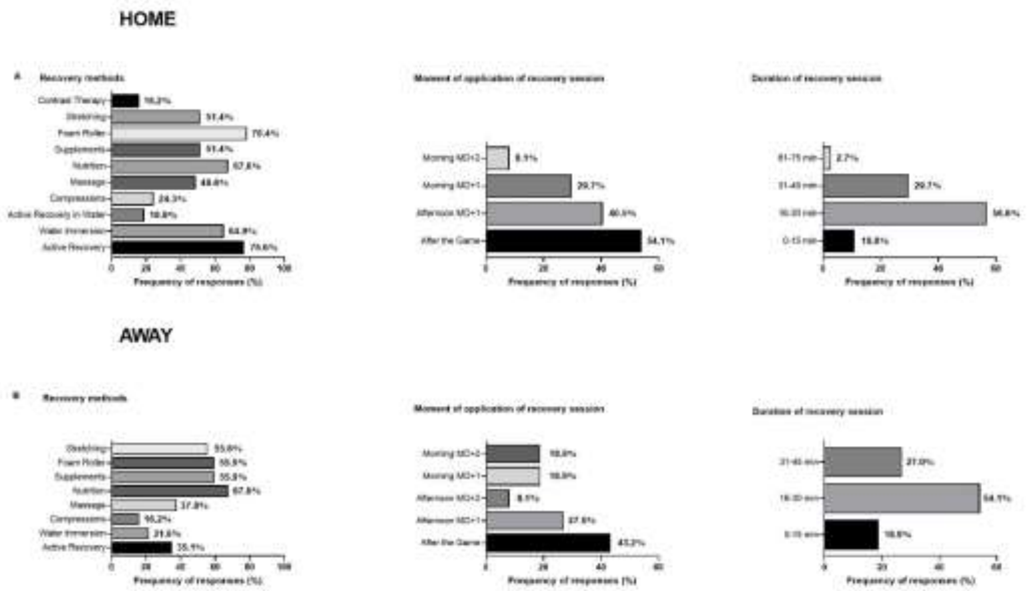
HRV: Heart rate variability

Recovery Practices

Figure 5 summarizes the REC methods, moment of the application, and duration after “home” and “away” competitions. Following “home” matches, foam roller (78.4%), active REC (76.6%), nutrition (67.7%), water immersion (64.9%), stretching (51.4%) and supplements (51.4%) were the main REC strategies. These were utilized after the match (54.1%), or afternoon MD+1 (40.5%), and lasted 16 – 30 min (56.8%), or 31 – 45 min (29.7%). Regarding “away” matches, nutrition (67.6%), foam roller (55.9%), supplements (55.9%), stretching (55.6%) are the main strategies used by S&Cc. The most frequent moments of application were reported to be after the match (43.2%), and afternoon MD+1 (27.0%), with durations of 16 – 30 min (54.1%) and 31 – 45 min (27.0%).

Figure 5 **A)** The percentage of the respondents answering the methods, moment of the application, and time range of the recovery session after a game at “home”. **B)**

The percentage of the respondents answering the methods, moment of the application, and time range of the recovery session after a game at "away".



MD: Match day

6.4. DISCUSSION

To the best of authors´ knowledge, this is the first study to describe the TL monitoring and physical performance assessment practices, the characteristics of ST and REC strategies in PRO futsal. As such, the present findings allow an overview of the current performance and injury mitigation strategies adopted by S&Cc in Spain and Portugal. The main results were: a) virtually all coaches reported monitoring TL, most of them through the use of subjective tools; b) neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and monitor fatigue; c) ST plays a crucial role in physical preparation in futsal and a typical ST session program consists of 3 sessions per week during the pre- and in-season; and d) multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following "home" and "away" matches.

Of note, the vast majority (97.3%) of the S&Cc from Portugal and Spain reported monitoring TL (either internal or external) in PRO futsal, which is in line with previous studies in high-level football and rugby clubs (146, 147). The most common method of recording TL was the RPE with 86.5%, followed by HR and GPS/accelerometry systems and that were used by 40.5% and 37.8%, respectively. Interestingly, these results contrast with those obtained in PRO soccer, where the majority of coaches reported to collect HR data and GPS/accelerometry and only a few utilize RPE and other subjective variables (21, 146). A possible explanation may be related to the fact that the use of GPS technology is inoperable in indoor sports (152), and that local positioning systems must be installed in the team's facilities, which limits its application in, for example, "away" games. As a consequence, the use of wearable tracking systems is somehow limited in futsal (i.e., it is not possible to obtain distance or velocity metrics), as only accelerometry data can be analyzed (152). Another potential factor explaining the differences between futsal and soccer with respect to TL monitoring is related to the economic disparities between both sports, since HR and GPS/accelerometry wearable technology are expensive (hence, more difficult to implement in futsal) and RPE is a "low cost" solution. In support of this notion, a previous study (147) in amateur rugby union found that the most common method to record TL was, indeed, RPE. From a practical perspective, the present results reinforce that, even in the absence of abundant economic resources, monitoring TL during the season is possible [and recommended], as shown by the high percentage of S&Cc that reported using subjective variables (e.g., RPE).

Considering player's physical capacities testing across the season, S&Cc generally evaluate body composition (81.1%), vertical jump ability (72.9%), muscular strength (70.3%), COD-agility (69.9%), followed by anaerobic capacity (54.1%) sprint (>10m) (51.4%), aerobic capacity (43.20%) and ACC ability (<10m) (40.6%) (Figure 3). These tests are usually conducted monthly (29.7%), biannually (27.0%), trimonthly (21.6%), weekly (16.2%), and bimonthly (10.8%). Regarding player's fatigue, S&Cc reported conducting assessments mostly every week (Figure 3) with vertical jump height, muscular strength, and HR variability being the variables most commonly tested. Remarkably, it seems that neuromuscular and strength capacities evaluations are used to evaluate both performance and fatigue during the season with different frequency between practitioners in futsal. These results are in line with previous research (149, 153) that have demonstrated that jump tests, strength measurements, and sport-specific assessment protocols are commonly used in other team-sports, implemented on a weekly or monthly basis. Noteworthy, other studies (146, 148) presented that S&Cc implement questionnaires or GPS/accelerometry systems to manage performance and fatigue status, which contrasts with the present investigation where these methods were reported to be used to control TL and not evaluate player's physical capacities. In applied settings, and according to the current practices in PRO futsal, it appears that S&Cc consider that evaluating players´ physical capacities during the season is valuable and allows for adjustments in the training plan to be made accordingly.

When inquired about ST, all practitioners reported it to be a significant and highly important training component in futsal (i.e., 4.8 ± 0.4 out of 5). Previous studies have confirmed the positive effects of ST on physical capacities in futsal (143, 154, 155). Specifically, Marques et al, (155) found significant improvements in physical performance (i.e., CMJ_{height}, sprint time, T-Test, kicking ball speed, and maximum strength in leg-press) following two weekly ST sessions complementing specific futsal training. In the present study, S&Cc reported prescribing ST mainly 3 times/week (55.6%), with sessions lasting 31 – 45 min (32.4%), 16 – 30 min (29.7%) or 46 – 60 (24.3%) in the Pre_{se}. During in-season, practitioners declared performing 3 weekly ST sessions (45.9%), but with shorter durations (16 – 30 min, 45.9%; 31 – 45 min, 27.0%; and 46 – 60, 21.6%) (Figure 4), most likely due to the limited time to dedicate to the development of physical qualities during the training week. A novel aspect within this investigation was related to how S&Cc vary their ST practices depending on the competitive calendar (i.e., normal vs congested weeks). Interestingly, the first ST during a normal week is performed mostly on the morning of MD +2 (43.3%) and comprises both lower and upper body lifts (73%) and core (67.6%) exercises. During congested periods, short (i.e., 16 – 30 min, 45.9% or 0 – 15 min, 24.3%) ST sessions focused on the core musculature (62.2%) and (to a lesser extent when compared to normal weeks) lower and upper limb exercises (45.9%) are executed in the morning of MD +2 (27.9%). However, these results should be interpreted cautiously as they are mainly anecdotal evidence and more research is needed on the effects of ST on players´ performance and REC profile during normal and congested weeks in futsal.

Considering REC methods in futsal, current evidence-based knowledge is poor (144) as only few studies have investigated this topic (156-159). Nevertheless, and although their results should be interpreted with caution due to some of the parameters used to evaluate REC, Rahimi et al. (157) found that utilizing foam rollers resulted in superior REC effects as assessed by subjective variables, and physical performance when compared to passive REC. Furthermore, Tessitore et al. (158) analyzed the effects of immediate postgame REC interventions (i.e., seated rest, supine electrostimulation, low-intensity land exercises, and water exercises), and found no significant differences amongst REC interventions for anaerobic indicators, hormonal responses, muscle pain, and players' perceptions of REC (i.e., questionnaires). Regarding the results obtained herein, it seems that S&Cc adjust REC approaches depending on the game location (i.e., "home" versus "away"). Precisely, active REC, water immersion, and massage therapy appear to be more utilized following "home" games when compared to "away" (76.6% vs 35.1%; 64.9% vs 21.6%; 48.6% vs 37.8%, respectively). However, foam roller, stretching, nutritional and supplementation strategies are independent of the game location as the percentages of each do not differ greatly. Of note, REC sessions are mainly taking place after the game (43.2% and 54.1% following "home" and "away" games, respectively) or on the afternoon of MD +1 ("home": 40.5%; "away": 27%) and last 15 – 30 min (Figure 5). Nevertheless, more research on the effects of different REC methods in futsal players and their individual response is warranted.

6.5. LIMITATIONS

Whilst this is the first study to investigate the coaches' methods for monitoring TL, player's physical capacities, and the programming of ST and REC sessions, it is not without limitations. It is important to acknowledge that the results are based solely on the beliefs, experiences or training philosophy of S&Cc and that different staff members (e.g., physiotherapists, nutritionists, etc.), who are directly involved in injury risk mitigation and REC strategies were not included. Furthermore, players did not participate in the survey, which limits access to important information such as whether they use further assistance on REC or physical preparation in their own time, outside club's facilities. These findings should not be generalized, as the data was collected only from practitioners working in Spain and Portugal and must be applied with caution due to the plethora of contextual factors (i.e., international and national tournaments, club´s philosophy etc.), team's resources, and players' individuality (e.g., sex or training background) that may have influenced the results. Still, describing coaches' perceptions and practices about the topics addressed herein is certainly vital for helping the futsal community understand its strengths, weaknesses, and opportunities for improvement in terms of TL and fatigue monitoring, physical preparation and REC.

6.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

This study provides a comprehensive insight into the TL monitoring, players' physical capacities assessment, and the characteristics of ST and REC practices in futsal in Spain and Portugal. All coaches reported monitoring TL, most of them through the use of subjective tools (e.g., RPE). As such, following the practices already implemented in other sports, futsal teams should provide more financial and technical support, to allow hiring more staff members and acquiring, for example, HR or GPS/accelerometry systems, in order to optimize training monitoring and prescription. Neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and fatigue. From an applied perspective, S&Cc should integrate tests in the training sessions to frequently obtain information on their athletes' performance/fatigue status. ST plays a crucial role in physical preparation in futsal. A typical ST session program consists of 3 sessions per week during the pre- and in-season, focused on upper and lower limb exercises and core strengthening. A possible solution to ensure that this training frequency is met, coaches may reduce the duration of the ST sessions during the competitive phase of the season Lastly, multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following "home" and "away" matches. In applied settings, S&Cc are advised to implement the above-mentioned REC strategies independently of game location.

VII – STUDY 3

VII. STUDY 3

EXTERNAL MATCH LOAD AND THE INFLUENCE OF CONTEXTUAL FACTORS IN ELITE FUTSAL

7.1. INTRODUCTION

Futsal is an indoor sport characterized as a high-intensity intermittent modality with high physical, technical, and tactical demands (1, 61). Due to its increased popularity, better understanding the activity profile of futsal match-play has been a main interest of practitioners and researchers. In this regard, several studies have investigated the match demands in futsal using different approaches, such as time-motion analysis (1, 3, 5, 81), physiological parameters monitoring (e.g. HR and VO_2) (4, 7) and, more recently, wearable technology tracking (GPS/accelerometer) (24, 25).

Through time-motion analysis, it was observed that, during a match, players execute ~30 sprints, comprising sequences 2, 3, and 4 consecutive sprints, separated by rest intervals of 30, 45, or 60 s (3). Match external load refers to the physical demands (i.e., ACC and DEC, COD and jumps) derived from position data or inertial measurement units (160). Recently, Ribeiro et al. (24), using GPS technology, reported that futsal players covered 3750 ± 1123 m, from which 135 ± 54 m were completed sprinting (>18 $km \cdot h^{-1}$). Moreover, players executed a great number of ACC (5 ± 2 $n \cdot min^{-1}$), and DEC (5 ± 2 $n \cdot min^{-1}$) relative to "court time" (24). These data confirm the importance of high-intensity efforts during futsal match-play. Still, when it comes to a precise quantification of actions such as ACC, DEC, and COD, evidence is still scarce. More research is warranted since studies investigating these variables using wearable technology analyzed only a small number of matches (24, 25).

When examining a futsal game's demands more thoroughly, different investigations (1, 4, 5, 7) have confirmed that the match activity tends to decrease from the 1st to the 2nd half. For example, Milioni et al. (7) found that total distance covered, distance per min, maximal isometric force and voluntary activation were inferior in the 2nd half when compared to the 1st in a simulated match. Bueno et al. (5) reported an increment of the percentage of standing and the distance covered at walking velocity in the 2nd half compared to the 1st; in contrast, the percentage of medium and high-intensity activity decreased in the 2nd half of an OFF game. Interestingly, data collected using GPS revealed no meaningful differences on metabolic, kinematics, and mechanical activity between halves (24). Due to these inconsistencies, further research is needed to better clarify the demands of each half.

Considering contextual factors, studies from different sports (161-166) suggest that opponent's ranking and match location or result may affect game demands. For instance, Goodale et al. (164) found that female rugby players covered higher total, medium- and high-intensity running distances during losses and against top-ranking opponents when compared to wins and bottom-ranked opponents. Moreover, Vescovi et al. (166), investigating the match demands and the impact of contextual factors in PRO female soccer, detected no differences between home versus away competition, but that the relative distance covered was greater during losses. Notably, when it comes to futsal, the influence of contextual factors has been addressed mainly from a technical-tactical perspective (26) but literature is scarce regarding external match load variations, particularly using wearable technology-derived variables. This information may result extremely helpful for coaches as determining match demands based solely on video-analysis tools may be considerably time-consuming and limit the proper quantification of non-locomotor activities influencing sports performance (e.g., impacts or collisions) (27). As such, a better understanding of match external loads monitored via wearable technology may help coaches and sports scientists to prescribe training sessions more related to the actual efforts and demands of competition, thus enhancing performance and potentially reducing the risk of injury.

Based on the previous, the main purposes of this study were: 1) to quantify the match external load and movement demands during competitive PRO futsal matches while identifying differences between time-periods (i.e., 1st and 2nd halves) using accelerometer-based technology; and 2) to investigate whether contextual factors (i.e., opposing team's ranking, match outcome, and location) affect external load variables during the match. It was hypothesized that there would be a significant decrease in the external load parameters in the 2nd half with respect to the 1st half and that external mechanical loads would be higher against top-ranked teams, in "wins" and during "home" games.

7.2. METHODS

7.2.1. Study design

A retrospective, observational, cohort study design was used. The match activity profile of elite male futsal players was collected using wearable technology (i.e., accelerometers [Catapult Innovation; Melbourne, Australia]) throughout the season 2019 – 2020 (20 Games). Consistent with the Liga Nacional de Fútbol Sala (LNFS) (1st Division of Spain) rules, games lasted 40 min and consisted of two 20-min halves separated by a 10-min break. Only 10 of the team's 15 players were monitored, because of the GPS availability. The study procedures did not influence or alter the match in any way. To compare team's ranking, the following criteria was determined: "high": the top five teams in the league (excluding the monitored team) (n = 6 matches); "medium": the following five teams (n = 8 matches); "low": the bottom five teams of the league (n = 6 matches). Match-outcome was classified as "win" (n = 13 matches), "loss" (n = 5 matches) and "draw" (n = 2 matches). Due to the small number of "draws", this condition was excluded from the present study. Match location was referred as "home" (n = 12) and "away" (n = 8).

7.2.2. Participants

Ten elite male futsal players (age: 26.7 ± 3.1 years old, body mass: 74.7 ± 5.9 kg, height: 1.78 ± 0.06 m, body fat: 8.8 ± 1.5%), members of a team competing in LNFS and finalists of the UEFA Futsal Champions League were monitored for this study. Only data from on-court players selected by the coaching staff in the Pre_{se} to wear the technology and that participated in at least 75% of the games throughout the season were considered for analysis. One of the players did not complete >75% of games due to injury and was excluded from the study's sample. As a consequence, 9 players (Back: n = 3; W: n = 4; P: n = 2) finally participated in the investigation. By signing a PRO contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

7.2.3. Procedures

Instrumentation: The activity profile data was collected via a portable GPS unit Catapult Sport Optimeye S5 (Catapult Innovation; Melbourne, Australia) comprising a tri-axial accelerometer, gyroscope, and magnetometer, which provide data for inertial movement analysis at a sampling rate of 100 Hz. Previous research has reported this technology to be valid and reliable (167). The devices were fitted to the upper back of each player using a specific vest under the athletes' jersey. To avoid potential inter-unit error, each player wore its own device, that was the same throughout the season (168). To represent the match-play cumulative load, data collection was initiated when players were in the locker room after the warm-up period, 10 min before starting the match and concluded before the postgame cool-down. All data were analyzed by Catapult Sport Openfield software (Catapult Innovation; Melbourne, Australia), which applies specific algorithms to transform the input of raw inertial data during athlete movement into meaningful and standardized output variables used to quantitate the movement experience.

Activity Profile Data: Variables of interest in this study included average and PL, PL·min^{-1}, ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI}. PL consists of the sum of the ACC across all axes of the internal tri-axial accelerometer during movement (100 Hz), applying the established formula (169) and expressed as an a.u. PL·min^{-1} divides the accumulated PL by time, providing an intensity index and expressed as an a.u (170). ACC_{HI} refers to the total inertial movements registered in a forward acceleration vector within the high band (>3.5 m·s^{-2}) and DEC_{HI} corresponds to the total inertial movements in a DEC vector within the high band (< -3.5 m·s^{-2}). COD_{HI} represents total inertial movements registered in a rightward/leftward lateral vector within the high band (>3.5 m·s^{-2}). Regarding the number (i.e., count) of ACC_{HI}, DEC_{HI}, and COD_{HI}, only high-intensity inertial movements were considered in the present research. EXPL-MOV encompass the total inertial movements irrespective of the direction (i.e., ACC, DEC, and COD; jumps not included) within the medium and high bands (>2.5 m·s^{-2}). Previous studies (171, 172) have already investigated and confirmed the validity and reliability of the aforementioned variables (i.e. ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI}).

7.2.4. Statistical analysis

Statistical analysis was performed in Jamovi statistical package (2020; Version 1.2). Data are presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was used to determine the differences among opposing team's level. Post-hoc pairwise comparisons were performed to identify significant main effects between high, medium, and low ranking teams. To detect differences between game periods (i.e., 1st and 2nd halves) a paired sample T-Test was applied. To analyze the contextual factors (i.e., Home-Away, and Win-Loss games), Independent Samples T-Tests were performed. Cohens's effect sizes (ES) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and very large (>2.0-4.0) (173). Significance level was set as $p \leq 0.05$.

7.3. RESULTS

Table 4 depicts the external match demands considering the full-game data as well as the 1st and 2nd halves separately (i.e., average values from all games). A significant and small-moderate decrease in total PL and $PL{\cdot}min^{-1}$ was observed in the 2nd half. Moreover, the number of DEC_{HI} and EXPL-MOV was significantly lower during the 2nd half, with small to moderate effect sizes. Small non-significant differences were obtained for ACC_{HI}, and COD_{HI}.

Table 4 Match-play demands and comparison between the 1st and 2nd halves

Variables		Full Game	1st Half	2nd Half	*p* value	ES
Total PL	a.u	3868 ± 594	1990 ± 299	1868 ± 344*	0.030	0.52
$PL{\cdot}min^{-1}$	a.u	10.8 ± 0.8	11.2 ± 0.9	10.4 ± 1.0*	0.001	1.16
ACC_{HI}	n°	73.3 ± 13.8	36 ± 7.3	37.3 ± 9.9	0.593	0.12
DEC_{HI}	n°	68.6 ± 18.8	38 ± 9.4	30.6 ± 11.3*	0.001	0.83
EXPL-MOV	n°	1165 ± 188	611 ± 97	559 ± 108*	0.017	0.58
COD_{HI}	n°	173 ± 29.1	89.5 ± 19.6	85 ± 16.4	0.410	0.18

Values expressed as mean ± SD.

*$p \leq 0.05$; significant first and second half difference by a Paired Sample T-Test.

ACC_{HI}: high-intensity acceleration; a.u: arbitrary units; COD_{HI}: high-intensity change of direction; DEC_{HI}: high-intensity deceleration; ES: effective size; EXPL-MOV: explosive movements; n°: number; PL: player load; $PLmin^{-1}$: player load per minute; SD: standard deviation.

Tables 5 and 6 display the external load variables according to the contextual factors. No significant differences were attained in external match load metrics regarding the opposing team's level, the match outcome, and the match location.

Table 5 Futsal match-play demands according to the opposing team's ranking position

Variables		High (n= 6)	Medium (n= 8)	Low (n= 6)	*p* value
Total PL	a.u	4021 ± 653	3802 ± 703	3804 ± 522	0.795
PL min^{-1}	a.u	10.3 ± 0.9	11.0 ± 0.9	11.0 ± 0.6	0.328
ACC_{HI}	n°	81 ± 5.5	71.7 ± 14.1	68.8 ± 16.6	0.625
DEC_{HI}	n°	73 ± 18.9	69.7 ± 19.5	64.5 ± 19.9	0.732
EXPL-MOV	n°	1217 ± 163	1171 ± 233	1122 ± 182	0.131
COD_{HI}	n°	185 ± 24.1	166 ± 39.5	170 ± 24.5	0.477

Values expressed as mean ± SD.

ACC_{HI}: acceleration; a.u: arbitrary units; COD_{HI}: change of direction; dEC_{HI}: deceleration; EXPL-MOV: explosive movements; n°: number; PL: player load; $PL{\cdot}min^{-1}$: player load per minute; SD: standard deviation.

Table 6 Match-play external load according to match result and location.

Variables		Match Result Win (n= 13)	Match Result Loss (n= 5)	*p* value	ES	Match Location Home (n = 12)	Match Location Away (n = 8)	*p* value	ES
Total PL	a.u	3846±623	3990±689	0.675	0.22	3757 ± 646	4036 ± 498	0.315	0.47
PL min^{-1}	a.u	11.0±0.7	10.2±1.0	0.082	0.97	11.0 ± 0.5	10.5 ± 1.0	0.174	0.64
ACC$_{HI}$	n°	72.1±16	79.4 ± 4.3	0.337	0.52	72.6 ± 15.9	74.4 ± 10.7	0.784	0.12
DEC$_{HI}$	n°	67.2±20.8	70.4 ± 19	0.766	0.15	67.4 ± 20.7	70.4 ± 16.7	0.741	0.15
EXPL-MOV	n°	1157±203	1210 ± 179	0.621	0.26	1134 ± 206	1212 ± 157	0.376	0.41
COD$_{HI}$	n°	171±1.1	182 ± 26.2	0.491	0.37	169 ± 33.6	180 ± 21	0.405	0.38

Values expressed as mean ± SD.

ACC$_{HI}$: high-intensity acceleration; a.u: arbitrary units; COD$_{HI}$: high-intensity change of direction; DEC$_{HI}$: high-intensity deceleration; ES: effect size; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

7.4. DISCUSSION

The present study investigated the external load demands of elite male's futsal match-play by describing six variables (i.e., PL, PL·min^{-1}, number of ACC$_{HI}$, DEC$_{HI}$, EXPL-MOV and COD$_{HI}$) collected via wearable technology. The current research is of interest for practitioners as it provides descriptive data pertaining to a top-3 futsal team competing in Spain's 1st Division that was monitored throughout the entire season. Remarkably, for the first time, we identified, by accelerometry-based data, that a significant decrease in PL, PL·min^{-1}, DEC$_{HI}$, and EXPL-MOV occurs in the 2nd half when compared to 1st. In contrast, other variables such as ACC$_{HI}$, and COD$_{HI}$ appear to not decline significantly as the match progresses. Finally, another key finding was that contextual factors (i.e., opponent team's level, match outcome, and match location) seem not to influence the external match-load metrics.

Regarding match demands, the present results reinforce previously published research (1, 3-5, 24, 83) and confirm, through accelerometry data, that futsal is, indeed, a high-intensity intermittent modality in which players perform multiple ACC_{HI}, DEC_{HI}, and COD_{HI} actions (61). Specifically, players were found to perform, on average, around 1165 ± 188 moderate-to-high-intensity explosive actions (> 2.5 $m \cdot s^{-2}$) in all planes of movement during a single match. These results are in line with a previous study (24) that investigated the external match-demands by GPS and reported that futsal players may perform around 80 ACC and DEC actions during match-play. From a practical standpoint, identifying these variables is extremely useful for S&Cc to prepare more specific training plans according to the demands that players are expected to encounter during competition, and to plan safer return-to-play protocols.

Of note, when analyzing game periods (i.e., halves), players displayed higher total PL, $PL \cdot min^{-1}$, and DEC_{HI} and EXPL-MOV in the 1st half when compared to the 2nd. Similar results were obtained by other authors (1, 4, 5, 7) using time-motion analysis and indicating that the percentage of distance covered at medium and high-velocity, and sprinting was greater during the 1st half. However, reports of no meaningful differences between the two halves can also be found in the literature (3, 24). For example, Ribeiro et al. (24) found that kinematic (i.e., distance covered per min, sprints), mechanical (i.e., ACC, DEC), and metabolic variables (i.e., metabolic power per min) weren't affected by time-periods. These contradicting results could be explained by different factors related to futsal's characteristics (e.g., unlimited number of substitutions), or tactical decisions (e.g. "fly-goalkeeper"). Further research on the influence of tactical behaviours in external match load activities (i.e., complementing the recent work by Rico-González et al., (26)) is warranted. Based on the previous, S&Cc should prepare the players to be able to complete and tolerate high-intensity activities until the end of the game.

Regarding the influence of the opposing team's ranking on the league, no meaningful differences were observed on any external load variable which indicates that similar physical demands are placed on players, when playing against the top or bottom competitors, in order to achieve a positive result. Along the same lines, related studies (161, 165) on other team-sports have displayed similar physical match-demands against low-, medium- and, high-level opponents. However, Goodale et al. (164) found that total distance covered and activities at moderate and high-speeds were higher when playing against the top-4 opponents when compared to the bottom-4. From an applied perspective, these findings suggest that players are exposed to high mechanical loads irrespective of the level of the opposing team; hence, from a physical preparation standpoint, TL should not be greatly altered the week prior to playing, for example, a bottom-ranked team.

Considering match result (i.e., Win-Loss), no significant differences were found on external match load. The present data do not seem to support a previous study (163) that found that the number of jumps, ACC_{HI}, DEC_{HI}, and COD were higher during losses when compared to wins in basketball. Additionally, Vescovi et al. (166) observed that relative sprint distance was greater during losses than draws in PRO women soccer players. It is probable that tactical aspects could explain these disparities as, in futsal, it is common for teams to follow the same tactical move when losing the match: playing with a "fly-goalkeeper" which "slows down" the game. In applied settings, coaches and sports practitioners should consider that players are exposed to similarly high match demands after losing (in comparison with wins or draws), and that appropriate TL management is necessary. Therefore, the tendency to train "harder" after losses should be avoided as it could lead to detrimental effects on players' physical performance.

The external match load and activity profile were similar regardless of the game location (i.e., home versus away). Given that during the season travel time does not usually exceed ~3 hours by flight or bus in Spain, travel fatigue would most likely not affect players' performance. Moreover, most of the players had experience playing in national and international leagues (i.e., LNFS, Champion League), which ensures a high level of familiarity with travelling. Previous research (162, 166) from other team-sports supports the present results. PRO female soccer's players were found to experience no differences on physical demands irrespective of match location (166). Conversely, related studies (174, 175) have reported a significant decline on performance when playing "away" compared to "home". Still, caution is necessary when comparing results from different studies. There are important factors that could influence the outcomes such as sport characteristics (i.e., futsal, soccer, and rugby), travel time or even time-zone changing since long-haul, and trans meridian travelling has been suggested to affect players' performance (176, 177).

7.5. LIMITATIONS

This study is limited by its small sample size. Nevertheless, it is worth noting that the present research presents accelerometry-based match data from a total of 20 games from a PRO, top-3 LNFS team and finalist of the UEFA Champions League. Previous studies using similar technology analyzed six (24) and three (25) games and both coincided that studies comprising a greater number of matches are necessary. A second limitation is that the match external load was monitored only for on-court players, and no goalkeepers' demands during the match-play were considered. Lastly, it is limited by the difference between the total number of matches classified as "win" (n = 12) and "loss" (n = 5).

7.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

From an applied perspective, based on the findings herein, intermittent game-based drills that require multiple high-intensity efforts (e.g., short sprints in multiple directions or DEC) and speed-power exercises should be prioritized in training. These activities will seemingly prepare players to perform and tolerate activities similar to the ones they may encounter during match-play. Additionally, and in contrast with the initial hypothesis, contextual factors (i.e., team ranking, match result, and location) appear not to affect the external match-load in futsal; thus, coaches should not substantially alter their weekly training plan (from a physical preparation perspective) whether the team plays home or away, or against a top- or bottom-ranked opponent. Lastly, coaches and sports scientists can utilize these results as a reference to design specific training and return-to-play plans.

Through the analysis of accelerometry-based data, this study indicates that futsal players are exposed to high mechanical external loads, and perform a great number of ACC_{HI}, DEC_{HI}, COD_{HI}, and EXPL-MOV during a match. Additionally, higher total PL, $PL{\cdot}min^{-1}$, DEC_{HI}, and EXPL-MOV are obtained in the 1st half when compared to the 2nd. Contextual factors (i.e. match result, team´s ranking and match location) do not seem to affect any of the external variables studied. Coaches and sport scientists should consider the present findings when plaining specific training sessions and return-to-play approaches from an injury perspective.

VIII – STUDY 4

VIII. STUDY 4

DIFFERENCES BETWEEN OFFICIAL AND NON-OFFICIAL MATCHES IN WORST-CASE SCENARIOS IN ELITE FUTSAL PLAYERS

8.1. INTRODUCTION

Futsal is a high-intensity intermittent indoor sport, in which players are exposed to repetitive high-demanding scenarios during match-play (61, 62). A recent study (133) reported, through wearable technology (i.e., accelerometry) data, that futsal players perform around ~70 ACC_{HI}, DEC_{HI}, and ~170 COD_{HI} during OFF games. Moreover, players have been found to cover around ~3700 m in a single match, of which ~135 m are spent on high-speed running actions (>18 $km \cdot h^{-1}$) (24).

Of note, the type of games in futsal (i.e., OFF and Non-OFF) may influence match-play demands. Specifically, PRO players have been reported to spend ~12% and ~5% of the whole game duration in high-intensity running and sprinting actions in a simulated match (i.e., 4 × 10 min), values lower than the ~14% and ~9% found during OFF competition (1, 4). Likewise, the time of REC between sprint bouts is higher in Non-OFF (i.e., ~40 s) when compared to OFF matches (~15 s) (3, 4). Considering physiological parameters, a study (1) found that players spent 83% of the playing time above 85% of the HR_{max} in OFF games as opposed to another investigation that reported that only 36% of the total time was spent at >80% of the HR_{max} in Non-OFF matches (9). For this reason, to prepare players adequately to cope with training and competition loads during the season, practitioners should be conscious that their athletes are exposed to dissimilar stress levels depending on the type of the game.

Regarding the quantification of the match demands, different methods (i.e., "average approach" or "worst-case scenarios" [WCS] methods) have been used to measure and analyze the mechanical stress that players are exposed to during the match. The WCS approach relates to the quantification of the most intense period of the game or training (28) and is becoming increasingly popular in team-sports, such as soccer (29, 30), rugby (28), Australian football (31), futsal (32), and field-and ice-hockey (33, 34), to assess fluctuations in match demands by dividing time-play into discrete “epochs”. The WCS may be considered more accurate to quantify the most intense periods of the game, because the “average approach” may overlook variations and obscure the most intense periods of the play (35).

Depending on the availability of wearable technology (i.e., GPS vs accelerometry) and sport (i.e., indoor vs outdoor), PL, PL·min^{-1}, total distance, and high-speed running have been the most commonly investigated variables with time windows ranging from 30 s to 10 min in length (28-33). Within the WCS approach, the FIX was first developed (36), and consisted of splitting the time into fixed-periods (e.g., 1–30 s, 31–60 s, etc.). However, quantifying WCS by ROLL is considered more accurate, as this technique detects the exact period (e.g., 1–30 s, 2–31 s, etc.) in which players reached the highest intensity (37, 38). For example, Fereday et al. (178) found that the FIX method underestimates the relative total and high-speed distances during match-play when compared to ROLL in soccer players (178). Still, when it comes to futsal, literature is scarce about the quantification of WCS of different matches (i.e., OFF and Non-OFF) and using different methods (i.e., ROLL and FIX).

Therefore, this study aimed to compare and analyze the WCS in futsal considering: 1) OFF and Non-OFF matches; 2) calculated by two methods (i.e., ROLL and FIX); and 3) four different time-periods (i.e., 30 s, 1, 3, and 5 min). Due to futsal´s characteristics (61), we hypothesized that WCS would be higher: 1) in OFF when compared to Non-OFF matches; 2) when considering smaller (e.g., 30 s and 1 min) rather than larger time-epochs (e.g., 3 and 5 min), and 3) when calculated by ROLL in comparison to FIX.

8.2. METHODS

8.2.1. Study Design

An observation longitudinal study was designed. Match-play data from 26 games (i.e., 13 OFF and 13 Non-OFF) were collected using wearable technology (i.e., accelerometers) throughout the seasons of 2019/2020 and 2020/2021. OFF consisted of national (e.g., LNFS; 1st Division of Spain) or international (e.g., UEFA Champion League) games, and Non-OFF consisted only of friendly matches.

Consistent with the LNFS rules, games lasted 40 min divided into two 20 min halves and separated by a 10 min break. Only on-court players (i.e., starters and substitutes) were monitored (i.e., 12 players). The study procedures did not influence or alter the match in any way. Four WCS time-periods (i.e., 30 s, 1, 3, and 5 min) were analyzed by the ROLL and FIX methods.

8.2.2. Participants

Twelve elite male futsal players (age: 26.7 ± 3.1 years old, body mass: 73.6 ± 5.4 kg, height: 1.77 ± 0.04 m, body fat: 8.9 ± 1.7%), competing in LNFS and the UEFA Futsal Champions League were monitored. By signing a PRO contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

8.2.3. Procedures

Instrumentation: The activity profile data were collected via Catapult Sport Optimeye S5 portable GPS units (Catapult Innovation; Melbourne, Australia) comprising a tri-axial accelerometer, a gyroscope, and a magnetometer, which provide data for inertial movement analysis at a sampling rate of 100 Hz. Previous research has reported this technology to be valid and reliable (167). The devices were fitted to the upper back of each player using a specific vest under the athletes' jersey. To avoid potential inter-unit error, each player wore the same device throughout the seasons (168). To represent the match-play cumulative load, data collection was initiated when players were in the locker room after the warm-up period, 10 min before starting the match, and concluded before the postgame cooldown. All data were analyzed by Catapult Sport Openfield software (Catapult Innovation; Melbourne, Australia) and exported to a custom-built Microsoft Excel spreadsheet for further analysis. PL consists of the sum of the ACC across all axes of the internal tri-axial accelerometer during movement (100 Hz), applying the established formula and expressed as an a.u. (169). PL·min^{-1} divides the accumulated PL by time, and provides an intensity index (170).

Rolling Average and Fixed-Periods Length: To determine the WCS, data were extracted in each second interval for each player into a Microsoft Excel spreadsheet. ROLL was calculated by rolling time length of 30 s, 1, 3, and 5 min, (e.g., 1 – 30 s, 2 – 31 s, and so on) for the whole match, and by selecting the most intense passage for all the players individually (coefficient of variation [CV] 30 s: 10.9%; CV 1 min: 10.4%; CV 3 min: 10.4%; CV 5 min: 11.6%). FIX was obtained by splitting the total match into fixed-periods (e.g., 1 – 30 s, 31 – 60 s, etc.), from the start to the end of the game (CV 30 s: 12.1%; CV 1 min: 12.2%; CV 3 min: 13.1%; CV 5 min: 13.4%). For both methods, the highest intensity for every player in four time-windows (i.e., 30 s, 1, 3, and 5 min) was considered for analysis.

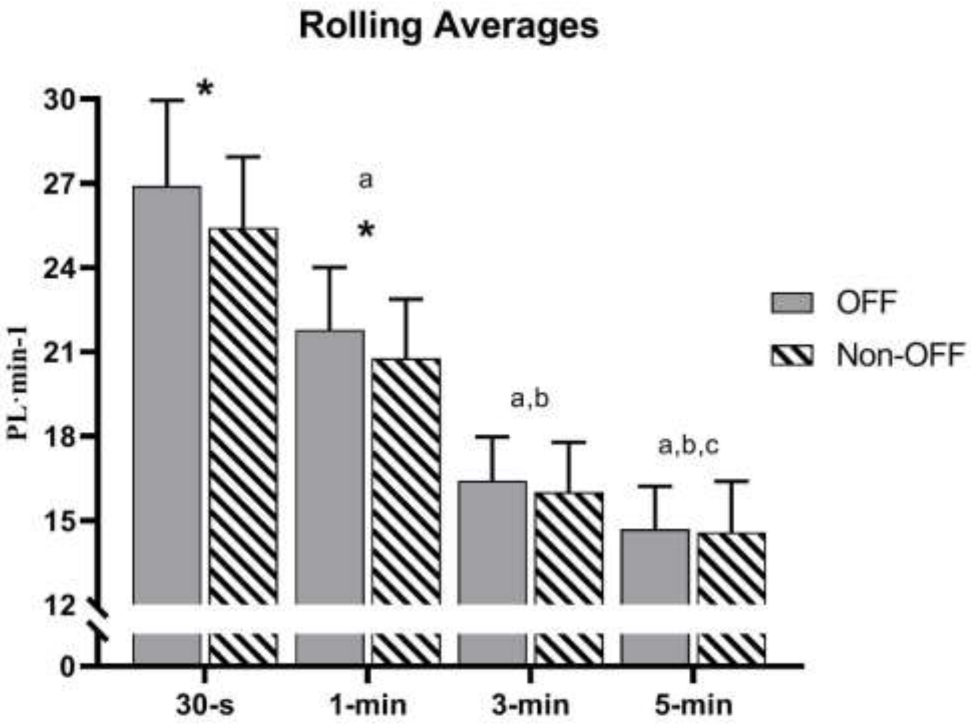
8.2.4. Statistical Analysis

The statistical analysis was performed using the Jamovi statistical package (2020; 1.6). Data are presented as mean and standard deviation (SD). Descriptive statistics were calculated for the types of game (i.e., OFF and Non-OFF), WCS duration (i.e., 30 s, 1, 3, and 5 min) and methods (i.e., ROLL and FIX). The assumption of normality in each variable was analyzed using the Shapiro-Wilk test. An independent T-Test was used to detect differences between WCS in OFF and Non-OFF games. A Non-Parametric Friedman repeated-measures ANOVA was completed to identify differences between the different WCS durations. A paired Sample T-Test was used to analyze the differences between the ROLL and FIX methods. Cohen's effect sizes (ES) with 95% confidence intervals (95% CI) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), and very large (>2.0–4.0) (173). The significance level was set at $p \leq 0.05$.

8.3. RESULTS

Figure 6 depicts the WCS (considering the PL·min^{-1}) in intervals of 30 s, 1, 3 and 5 min and the differences between OFF and Non-OFF games and time-periods, calculated by ROLL. Significantly more intense WCS were found in OFF when considering 30 s (p =0.001; ES [95% CI] = -0.53 [-0.79 – -0.28]) and 1 min (p = 0.001; ES [95% CI] = -0.47[-0.72 – -0.21]) intervals in comparison to Non-OFF. Conversely, non-significant and trivial to small differences between game types were observed when analyzing 3 min (p = 0.060; ES [95% CI] = -0.23 [-0.48 – 0.01]) and 5 min (p = 0.605; ES [95% CI] = -0.06 [-0.31 – 0.18]) epochs. Regarding the different time-periods, 30 s intervals yielded greater WCS than all other periods (30 s – 1 min: p = 0.001; 30 s – 3 min: p = 0.001; 30-s – 5 min: p = 0.001), and 1 min intervals were found to be more intense than 3 and 5 min ones (1 – 3 min: p = 0.001; 1 – 5 min: p = 0.001). Finally, significant differences were obtained when comparing 3 to 5 min intervals (p = 0.001).

Figure 6 Worst-case scenarios in official and non-official matches calculated over rolling-averages of 30 s, 1 min, 3 min and 5 min in length.



Values expressed as mean ± SD.

*p ≤ 0.05; significant difference between official and non-official analyzed by an Independent T-Test.

a: significantly different than the 30 s time-interval;

b: significantly different than the 1 min time-interval;

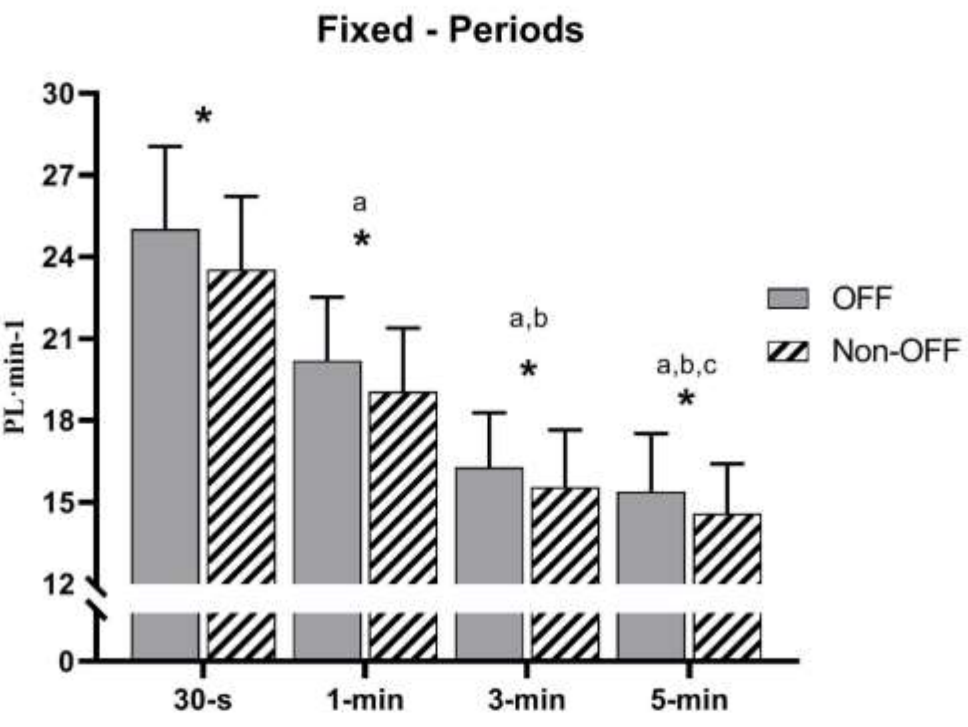
c: significantly different than 3 min time-interval.

OFF: official; Non-OFF: non-official.

Figure 7 presents the WCS (considering the PL·min^{-1}) during 30 s, 1, 3, and 5 min intervals and the differences between OFF and Non-OFF games and time-epochs, calculated by the FIX. Significantly more intense WCS were found in OFF when considering 30 sec (p = 0.001; ES [95% CI] = -0.52 [-0.78 – -0.26]), 1 min (p =

0.001; ES [95% CI] = -0.49 [-0.75 – -0.23]), 3 min (p = 0.001; ES [95% CI] = -0.35 [-0.60 – -0.09]), and 5 min intervals (p = 0.001; ES [95% CI] = -0.40 [-0.66 – -0.15]) in comparison to Non-OFF. Regarding the different time-windows, 30 s presented greater WCS than all other periods (30 s – 1 min: p = 0.001; 30 s– 3 min: p = 0.001; 30 s – 5 min: p = 0.001) and 1 min intervals were found to be more intense than 3 and 5 min (1 – 3 min: p = 0.001; 1 – 5 min: p = 0.001). Finally, significant differences were obtained when comparing 3 to 5 min (p = 0.001).

Figure 7 Worst-case scenarios in official and non-official matches calculated over fixed-periods of 30 s 1 min, 3 min, and 5 min in length.



Values expressed as mean ± SD.

*p ≤ 0.05; significant difference between official and non-official analyzed by an Independent T-Test.

a: significantly different than the 30 s time-interval;

b: significantly different than the 1 min time-interval;

c: significantly different than 3 min time-interval.

OFF: official; Non-OFF: non-official.

Table 7 describes the differences in WCS between the two methods (i.e., ROLL vs FIX). Significant and trivial to moderate differences were obtained between the two methods considering 30 s (p = 0.001; ES = 0.98), 1 min (p = 0.001; ES = 0.97), and 3 min (p = 0.001; ES = 0.18) periods. In contrast, non-significant and trivial differences were found for 5 min intervals (p = 0.107; ES = -0.18).

Table 7 The differences in the intensity calculated by rolling averages and fixed-periods among time-windows.

Time - Window	$PL \cdot min^{-1}$ (a.u)		Mean Diff (%)	*p* value	ES	95% CI
	Rolling	Fixed				
30-s	26.1 ± 2.84	24.2 ± 2.93	1.77 ± 0.12	0.001*	0.98	0.83 – 1.13
1-min	21.2 ± 2.21	19.6 ± 2.39	1.70 ± 0.10	0.001*	0.97	0.82 – 1.12
3-min	16.2 ± 1.68	15.9 ± 2.08	0.47 ± 0.10	0.001*	0.18	0.06 – 0.30
5-min	14.6 ± 1.69	14.9 ± 2.00	-0.14 ± 0.11	0.107	-0.18	-0.30 – -0.05

Data presented as mean ± SD; *p ≤ 0.05; significant differences analyzed by a Paired Sample T-Test. a.u.: arbitrary unit; CI: confidence interval; Diff: difference; ES: effect size; min: minutes; SD: standard deviation; s: seconds.

8.4. DISCUSSION

To our knowledge, this is the first study that compared the WCS between OFF and Non-OFF matches considering different time-periods in futsal. The main findings indicate that 1) the ROLL approach showed that OFF matches present higher intensity (i.e., $PL \cdot min^{-1}$) when short time-intervals (i.e., 30 s and 1 min) are considered in comparison to Non-OFF; however, no differences exist between games when analyzing large time-windows (i.e., 3 and 5 min); 2) significant differences were observed between matches in all time-periods when using the FIX method; 3) significantly higher WCS were determined as time-epochs increased in duration from 30 s to 5 min irrespective of the approach used; and 4) when compared to ROLL, FIX underestimates the WCS in 30 s, 1, and 3 min intervals but not 5 min.

Match-play intensity during OFF competitions (e.g., LNFS and UEFA Futsal Champions League), as determined by $PL \cdot min^{-1}$ and calculated via ROLL, was found to be higher than during Non-OFF matches when considering the time-windows of 30 s and 1 min. This could be explained by the importance of the OFF games, in which "winning" is the main goal, and players are more likely to engage in maximal intensity efforts as opposed to friendly matches that are mainly focused on developing tactical, technical, and physical capacities (179). Comparing ACC, DEC and metabolic power measures between OFF and friendly matches in soccer, differences in match activities were identified as well (180). Moreover, it should be taken into account that Non-OFF games take place mainly during Pre_{se} (i.e., a period of increased TL) compared to the OFF ones that are held during the season, a period in which, in theory, players are closer to the peak of their performance. Notably, no difference in WCS was found between the matches as time-windows increased (e.g., 3 and 5 min intervals). It appears that larger time-epochs (i.e., >3 min) may obscure the most intense periods of the OFF competitions and overlook the "actual intensity" of these matches, possibly because futsal players barely spend >5 min on the court due to unlimited substitutions (26). In brief, WCS calculated over longer intervals seem to be closer to the match average intensity obtained with the "average approach". From an applied perspective, 30 s and 1 min intervals should be analyzed when determining the WCS, as they are the only ones that allow discriminating between OFF and Non-OFF matches. Moreover, sports practitioners should be conscious that athletes are exposed to high physical stress during friendly matches but that the reached WCS are lower than those of the OFF competitions. Still, Non-OFF should be periodized accordingly, with sufficient REC (essentially during the preparatory phase) as match time-exposure has been shown to cause more injuries than training time-exposure (i.e., 61.1 injuries/1.000 match hours vs 9.9 injuries/1.000 training hours) during the Pre_{se} (181).

Regarding the different WCS computation methods, the FIX approach underestimated the intensity in futsal matches when compared to the ROLL in 30 s, 1, and 3 min intervals. These results are in line with previous research from different team-sports (30, 36, 37). For example, Cunningham et al. (37) found that the FIX method undervalued the maximum and high-speed running distance covered irrespective of the time-window (i.e., 60 – 300 s) in rugby players. Similar results were obtained in soccer players, with the FIX method underestimating the relative total and high-speed distances during match-play when compared to ROLL (178). Interestingly, no significant differences between the two methods were found within the 5 min time-window herein. Again, this finding supports that the utilization of large time-periods to determine the WCS is not recommended, as they do not accurately portrait the game's most demanding passages. The intensity significantly declines as time extends from 30 s to 5 min by both the FIX and ROLL approaches. In applied settings, the WCS provide useful information for practitioners to optimize training and rehabilitation prescription. By better understanding the demands of the most intense periods, coaches can monitor training drills to ensure that players are exposed to such scenarios, particularly in technical-tactical training.

8.5. LIMITATIONS

Whilst this is the first study that provides the WCS from an elite futsal team (UEFA Champion League Finalist) in different types of match, it is limited by the fact that only four WCS time-windows (i.e., 30 s, 1, 3, and 5 min) and one external load variable ($PL \cdot min^{-1}$) were considered. Furthermore, this study was limited by the small number of players and the fact that only one team was recruited, which leads to analyzing only specific tactical behaviors and the style of the training. Other metrics, such as high-speed running distance or ACC/DEC, COD, and collisions need to be considered while quantifying the WCS, as they may affect the most intense periods of the game (182). A holistic approach to the quantification of the WCS that incorporates a range of external and internal load variables is needed in order to provide a better understanding of the most demanding passages during futsal competition because WCS may occur under multivariate conditions as mentioned above (182). Regarding future research, it would be interesting to analyze how technical-tactical parameters can influence the WCS (182), how these are influenced by the context of situational variables (e.g. 5 vs 4 game in the court, home vs away advantage etc.), and the model of the game and the effectiveness of actions in the match (183). Lastly, more research comparing the most intense periods of match-play between youth and PRO matches to assist practitioners in planning and optimizing long-term player development is warranted.

8.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In line with the initial hypothesis, OFF matches presented higher WCS when compared to Non-OFF competition, quantified by ROLL. However, through this computation method, differences between match types were identified only when short time-intervals (i.e., 30 s and 1 min) were used. Considering the FIX approach, significant differences in WCS between the OFF and Non-OFF games were found in all time-windows. Moreover, this method significantly underestimated the WCS from 30 s to 3 min, but not in the 5 min time-epoch compared to ROLL. Lastly, irrespective of the computation method, 30 s intervals were found to display the highest WCS and 5 min, the lowest.

WCS may provide coaches with useful information to optimize training and rehabilitation practices since a better understanding of the demands of the most intense periods of the game can be used to monitor training drills, particularly during technical-tactical training and allow a more progressive return to competition. From an applied perspective, based on the present data, sport practitioners are advised to use short time-periods (i.e., 30 s and 1 min) to quantify the WCS in futsal as these were the only ones found to be able to discriminate between different types of matches (i.e., OFF and Non-OFF). Conversely, larger time-periods (i.e., 3 and 5 min) appear to obscure the "actual intensity" to which the players are exposed. In addition, ROLL seems to be more accurate than FIX to detect the WCS in elite futsal matches.

IX – STUDY 5

IX. STUDY 5

ANALYSIS OF THE COUNTERMOVEMENT JUMP VARIABLES ACCORDING TO COMPETITIVE LEVELS AND PLAYING POSITIONS IN FUTSAL

9.1. INTRODUCTION

Futsal is a high-intensity intermittent sport in which, during match-play, players perform a great number of ACC, DEC, COD, and EXPL-MOV (24, 61, 133). For example, PRO futsal players have been shown to cover ~3750 m, from which ~135 m are performed at high-intensity running velocities (> 18 $km \cdot h^{-1}$), and complete ~5 ACC and ~5 DEC per min of "court time" (24). When compared to SEMI-PRO competition (e.g., national state team), match physical demands are higher in PRO (e.g., international level team), with players covering a 42% greater total distance (~4300 m vs. ~3000 m), completing a higher number of sideways or backward movements, and total overall activities (i.e., ~470 vs. ~310) (6). For this reason, well-developed physical capabilities play a crucial role in futsal, as they allow players to cope with the high-intensity demands of match-play.

Regarding neuromuscular performance, several studies (50, 57, 58, 106, 107, 184) found that PRO players significantly outperform SEMI-PRO in sprint, repeated sprint ability, standing broad jump, and COD and reactive agility tests. Remarkably, when it comes to jumping ability, PRO players have been reported to present similar values in CMJ_{height} when compared to their SEMI-PRO counterparts (50, 57, 58). However, CMJ_{height} alone may not be sensitive enough to analyse the neuromuscular characteristics (i.e., explosiveness, fatigue, adaptation, etc.) of an athlete or to detect changes in the jump strategy (ECC – CON phase metrics) as a consequence of training or competition stimuli (60, 185). Therefore, a more comprehensive analysis of kinetic variables during the jump-land cycle in both PRO and SEMI-PRO futsal players is warranted, particularly taking into account that vertical force production plays a crucial role in athletic actions, such as sprinting and COD (41).

Considering players' positional demands, recent studies (32, 83, 186) demonstrated that match activities vary amongst positions (i.e., D, W, and P).

However, Caetano et al. (3) found no match demands positional differences in terms of sprint distance, peak velocity, recovery time between consecutive sprints, and number of sprints per minute. Interestingly, only one study (187), evaluated jumping ability (i.e., CMJ_{height}) amongst playing positions in futsal, and reported non-significant differences when comparing goalkeepers, D, W, and P. Again, no additional CMJ metrics were analysed and futsal practitioners could benefit from a more thorough playing position-specific analysis of the neuromuscular performance to prescribe tailor-made training programs.

To date, no studies have analyzed the differences in CMJ kinetic variables according to competition level (i.e., PRO vs. SEMI-PRO) and playing position (i.e., D, W, and P). Thus, the aims of this study were to: 1) compare several CMJ metrics (i.e., CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity) between PRO and SEMI-PRO futsal players; and 2) analyze the differences in the above-mentioned metrics among playing positions (i.e., D, W, and P). According to the futsal match demands highlighted above, we hypothesized that: 1) PRO players would present higher performance in all CMJ metrics when compared to SEMI-PRO players; and 2) no differences on CMJ variables would be found between playing positions due to the tactical and technical characteristics of the sport (that make players more flexible to changing or rotating positions (188).

9.2. METHODS

9.2.1. Study Design

This retrospective study was designed to compare the CMJ kinetics metrics between PRO and SEMI-PRO futsal players and amongst playing position. All players were evaluated after the Pre_{se} period (i.e., September [Sep]) during the seasons 2019-2020 and 2021-2022. CMJ data were collected following a standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., sub-maximal CMJ attempts). All evaluations were completed at the same time of the day, in the same facilities and following at least 24h of rest (i.e., training day-off) to avoid any acute or residual fatigue effects.

9.2.2. Participants

Fifty-six male futsal players (age: 25.2 ± 4.8 years; body mass: 74.4 ± 6.4 kg) were recruited from 4 different teams and classified as PRO or SEMI-PRO according to their competitive level. The former group consisted of 29 players (age: 27.0 ± 4.4 years; body mass: 75.4 ± 6.0 kg) that competed in the 1st Division of Spain (LNFS) whereas the latter consisted of 27 players (age: 22.7 ± 4.3 years; body mass: 73.1 ± 6.8 kg) competing in either the 2nd Division of Spain (n = 8), or the 2nd B Division of Spain (n = 19). Furthermore, all players were separated per position as follows: 16 D (age: 25.4 ± 3.7 years; body mass: 75.2 ± 6.0 kg), 26 W (age: 23.5 ± 4.5 years; body mass: 72.0 ± 6.9 kg), and 14 P (age: 28.0 ± 5.6 years; body mass: 77.8 ± 4.3 kg). Goalkeepers were not included in this study. All the recruited players were free from injury and completed the standard training program of their respective team during the weeks preceding the test session. All players provided individual consent for data collection and study participation. All procedures were approved by the Local Ethics Committee and conducted according to the Declaration of Helsinki.

9.2.3. Procedures

Vertical Jump Test: Players performed the CMJ test on a portable force platform (Kistler 9286BA, Kistler Group, Winterthur, Switzerland). All data were exported and analyzed with a specific software (ForceDecks, Vald Performance, Brisbane, Australia). Players were required to perform a downward movement followed by a complete, rapid extension of the lower-limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement and athletes were directed to jump as high as possible and land close to the take-off point. They executed two maximal trials with 1 min rest and the mean of the two jumps was retained for analysis. The following variables were selected: CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity. A total of 64 individual CMJ samples were analysed, as some participants were assessed both seasons.

9.2.4. Statistical Analysis

The results are reported as estimated marginal means with 95% confidence intervals. Before running linear mixed models, boxplots and histograms were used to identify and exclude potentially influential data points. Following this analysis, residual plots were visually inspected to determine deviations from homoscedasticity or normality. All assumptions were met, and the normality of the residuals was also assessed using the Kolmogorov-Smirnov test. Linear mixed models were constructed to examine differences in CMJ variables according to competitive level and playing position, accounting for individual repeated measures. In all linear mixed models, competitive level (two levels) and playing position (three levels) were used as fixed effect and player as random effect with a random intercept and fixed slope. All assumptions were met, and the normality of the residuals was assessed using the Kolmogorov-Smirnov test. Pairwise comparisons were performed using post-hoc tests. The t statistics from the mixed model were converted into Cohen's d effect sizes and associated 95% confidence intervals. Effect sizes were interpreted as follows: <0.2, trivial; 0.20–0.59, small; 0.60–1.19, moderate; 1.2–1.99, large; and ≥2.0, very large (189). An alpha level of $p \leq 0.05$ was set a priori for statistical significance. All tests used in this study displayed high levels of absolute and relative reliability (i.e., intraclass correlation coefficients [ICC] >0.90 and CV <10%). All data were analysed using a statistical package (Jamovi, version 1.8, 2021).

9.3. RESULTS

Descriptive data and statistical analyses for CMJ kinetic variables according to competitive level are presented in Table 8. PRO players displayed greater COM displacement ($p = 0.002$, ES = 0.83, moderate), higher ECC absolute ($p = 0.019$, ES = 0.61, moderate) and relative peak power ($p = 0.046$, ES = 0.52, small), and greater ECC peak velocities ($p = 0.004$, ES = 0.76, moderate) when compared to SEMI-PRO. Non-significant and trivial-to-small differences were observed in all other CMJ variables (ECC and CON phase) according to the competitive level.

Table 8 Comparison of countermovement jump variables according to competitive level

Dependent variable (units)	EMMeans (95%CI)		ES (95%CI)	Interpretation	p value
	PRO	SEMI-PRO			
Jump height (cm)	36.6 (35.1; 38.1)	35.9 (34.3; 37.5)	0.16 (-0.33; 0.66)	*Trivial*	0.516
Flight – contraction time	0.753 (0.715; 0.791)	0.760 (0.720; 0.800)	0.06 (-0.43; 0.55)	*Trivial*	0.813
RSI_{mod} (m/sec)	0.514 (0.483; 0.546)	0.506 (0.473; 0.540)	0.09 (-0.41; 0.58)	*Trivial*	0.726
Eccentric ("downward") phase					
Braking phase duration - Contraction Time	40.4 (38.6; 42.2)	41.1 (39.1; 43.1)	0.14 (-0.35; 0.64)	*Trivial*	0.577
COM Displacement (cm)	**32.7 (34.3; 31.2)**	**28.9 (30.6; 27.3)**	**0.83 (0.31; 1.34)**	***Moderate***	**0.002***
Dec phase duration (ms)	173 (161; 185)	155 (142; 168)	0.51 (0.01; 1.01)	*Small*	0.050
Duration (ms)	487 (461; 514)	476 (447; 504)	0.15 (-0.34; 0.65)	*Trivial*	0.544
Peak Force ABS (N)	1790 (1702; 1877)	1771 (1678; 1864)	0.07 (-0.42; 0.57)	*Trivial*	0.774
Peak Force REL (N)	23.6 (22.7; 24.5)	24.0 (23.1; 25.0)	0.15 (-0.35; 0.64)	*Trivial*	0.560
Peak Power ABS (W)	**1449 (1315; 1584)**	**1211 (1067; 1356)**	**0.61 (0.10; 1.11)**	***Moderate***	**0.019***
Peak Power REL (W)	**19.1 (17.4; 20.9)**	**16.5 (14.6; 18.4)**	**0.52 (0.01; 1.02)**	***Small***	**0.046***
Peak Velocity (m/s)	**1.32 (1.38; 1.25)**	**1.18 (1.25; 1.11)**	**0.76 (0.25; 1.27)**	***Moderate***	**0.004***
Concentric ("upward") phase					
Duration (ms)	262 (251; 273)	249 (237; 261)	0.41 (-0.03; 0.91)	*Small*	0.107
Peak Force ABS (N)	1857 (1777; 1937)	1836 (1751; 1921)	0.09 (-0.40; 0.59)	*Trivial*	0.719
Peak Force REL (N)	24.5 (23.8; 25.3)	24.9 (24.1; 25.8)	0.18 (-0.31; 0.68)	*Trivial*	0.475
Peak Power ABS (W)	4041 (3866; 4216)	3930 (3745; 4114)	0.22 (-0.27; 0.72)	*Small*	0.384
Peak Power REL (W)	53.3 (51.5; 55.2)	53.5 (51.6; 55.4)	0.03 (-0.46; 0.53)	*Trivial*	0.898
Peak Velocity (m/s)	2.79 (2.74; 2.84)	2.77 (2.71; 2.82)	0.13 (-0.36; 0.62)	*Trivial*	0.609

Notes/Abbreviations: ABS: absolute; CI: Confidence Interval; COM: center of mass; Dec: deceleration; ES: effect size; EMMeans: estimated marginal means; REL: relative; RSI_{mod}: reactive strength index modified.

Bolded p value indicates statistically significant difference ($P < 0.05$).

Descriptive data and statistical analyses for CMJ kinetic metrics according to playing position are presented in Table 9. No statistically significant differences ($p > 0.05$, ES ranging from 0.00 to 0.51, trivial-to-small) were observed in any of the CMJ variables when comparing among positions.

Table 9 Comparison of countermovement jump variables according to playing position.

Dependent variable (units)	EMMeans (95%CI)			Main effect	W vs. D		W vs. P		D vs. P	
	W	D	P	p value	ES (95%CI)	p value	ES (95%CI)	p value	ES (95%CI)	p value
Jump height (cm)	37.3 (35.8; 38.9)	35.1 (33.1; 37.1)	36.3 (34.2; 38.5)	0.217	0.51 (-0.06; 1.09)	0.083	0.24 (-0.39; 0.87)	0.464	0.29 (-0.37; 0.96)	0.391
Flight – contraction time	0.777 (0.738; 0.816)	0.756 (0.706; 0.806)	0.736 (0.683; 0.789)	0.813	0.19 (-0.38; 0.76)	0.516	0.40 (-0.24; 1.03)	0.220	0.19 (-0.48; 0.85)	0.580
RSI_{mod} (m/sec)	0.532 (0.500; 0.565)	0.499 (0.457; 0.541)	0.499 (0.455; 0.544)	0.341	0.36 (-0.21; 0.93)	0.214	0.38 (-0.25; 1.01)	0.239	0.00 (-0.67; 0.66)	0.989
Eccentric ("downward") phase										
Braking duration - Contraction Time	41.3 (39.4; 43.2)	41.7 (39.3; 44.0)	39.3 (36.7; 41.9)	0.359	0.07 (-0.49; 0.64)	0.801	0.39 (-0.24; 1.03)	0.225	0.45 (-0.22; 1.12)	0.187
COM Displacement (cm)	30.9 (32.6; 29.3)	30.2 (32.3; 28.1)	31.3 (33.6; 29.1)	0.742	0.16 (-0.41; 0.73)	0.581	0.09 (-0.53; 0.72)	0.768	0.25 (-0.41; 0.92)	0.456
Dec phase duration (ms)	164 (152; 177)	161 (145; 177)	166 (149; 184)	0.892	0.11 (-0.46; 0.67)	0.717	0.05 (-0.58; 0.68)	0.876	0.15 (-0.51; 0.82)	0.649
Duration (ms)	478 (450; 506)	467 (432; 502)	500 (462; 538)	0.430	0.14 (-0.42; 0.71)	0.618	0.30 (-0.33; 0.93)	0.349	0.44 (-0.23; 1.11)	0.203
Peak Force ABS (N)	1741 (1650; 1831)	1766 (1650; 1881)	1835 (1711; 1958)	0.470	0.10 (-0.47; 0.67)	0.732	0.39 (-0.24; 1.03)	0.223	0.28 (-0.39; 0.94)	0.417
Peak Force REL (N)	24.2 (23.3; 25.2)	23.7 (22.6; 24.9)	23.5 (22.3; 24.8)	0.636	0.19 (-0.38; 0.76)	0.516	0.28 (-0.35; 0.91)	0.379	0.08 (-0.58; 0.74)	0.812
Peak Power ABS (W)	1288 (1148; 1429)	1374 (1196; 1551)	1329 (1137; 1521)	0.750	0.22 (-0.35; 0.79)	0.453	0.11 (-0.52; 0.74)	0.733	0.12 (-0.55; 0.78)	0.733
Peak Power REL (W)	18.1 (16.2; 19.9)	18.4 (16.1; 20.7)	17.0 (14.5; 19.5)	0.694	0.07 (-0.50; 0.64)	0.811	0.22 (-0.41; 0.85)	0.502	0.28 (-0.39; 0.94)	0.414
Peak Velocity (m/s)	1.26 (1.32; 1.19)	1.25 (1.34; 1.17)	1.23 (1.32; 1.14)	0.879	0.02 (-0.55; 0.58)	0.950	0.16 (-0.47; 0.79)	0.624	0.13 (-0.53; 0.80)	0.697

Concentric ("upward") phase										
Duration (ms)	253 (241; 264)	252 (237; 266)	263 (247; 279)	0.513	0.02 (-0.54; 0.59)	0.935	0.33 (-0.30; 0.97)	0.300	0.35 (-0.32; 1.01)	0.311
Peak Force ABS (N)	1800 (1717; 1883)	1834 (1729; 1940)	1904 (1791; 2017)	0.334	0.15 (-0.42; 0.72)	0.607	0.48 (-0.16; 1.11)	0.141	0.31 (-0.36; 0.97)	0.368
Peak Force REL (N)	25.1 (24.3; 25.9)	24.7 (23.7; 25.7)	24.4 (23.3; 25.5)	0.611	0.18 (-0.39; 0.74)	0.540	0.31 (-0.33; 0.94)	0.344	0.11 (-0.55; 0.78)	0.738
Peak Power ABS (W)	3928 (3748; 4108)	3929 (3698; 4159)	4099 (3854; 4345)	0.485	0.00 (-0.57; 0.57)	0.999	0.36 (-0.27; 0.99)	0.264	0.34 (-0.32; 1.01)	0.313
Peak Power REL (W)	54.8 (52.9; 56.7)	53.0 (50.6; 55.3)	52.6 (50.0; 55.1)	0.294	0.35 (-0.22; 0.92)	0.233	0.45 (-0.19; 1.08)	0.169	0.07 (-0.59; 0.74)	0.828
Peak Velocity (N)	2.81 (2.76; 2.87)	2.74 (2.67; 2.81)	2.78 (2.71; 2.85)	0.257	0.48 (-0.09; 1.05)	0.102	0.23 (-0.39; 0.86)	0.466	0.26 (-0.40; 0.93)	0.441

Notes/Abbreviations: ABS: absolute; COM displacement: centre of mass displacement; Dec: deceleration: EMMeans: estimated marginal means; REL: relative; RSI_{mod}: reactive strength index modified.

9.4. DISCUSSION

The present study is the first comparing the CMJ kinetic metrics between PRO and SEMI-PRO futsal players and examining the differences among playing positions (i.e., D, W, and P). The main findings were that: 1) PRO players displayed superior ECC capabilities, performing a higher COM displacement, generating greater absolute and relative peak power, and achieving greater peak velocities during the ECC phase when compared to SEMI-PRO players; and 2) non-significant differences were found in any CMJ variables when considering playing positions.

Regarding jumping ability between competition levels, previous studies (50, 57) that PRO players presented similar CMJ_{height} values when compared to SEMI-PRO players, which is in line with the results obtained herein. This implies that CMJ_{height} alone may not be the most suitable metric to discriminate players of superior competitive level or to be used for talent identification purposes. Conversely, when conducting a more comprehensive analysis of the kinetic variables during the jump-land cycle, PRO players displayed superior outcomes in several metrics of the ECC (i.e., downward) phase (i.e., COM displacement, ECC absolute and relative peak power, and ECC peak velocity) than their lower-level counterparts. This difference could be explained, at least in part, by the higher number of matches and training sessions that PRO players are exposed to (i.e., ~50 vs ~30 games per competitive season and ~6 vs ~3 training sessions per week) when compared to SEMI-PRO. It is important to highlight that PRO players must cope with higher physical match-demands and had more years of experience performing specific movement patterns of the sport, thus, potentially developing superior ECC capabilities, stretch-shortening cycle mechanisms and muscle-tendon properties compared to lower-level players (40, 66). Furthermore, it is noteworthy reporting that the observed differences according to the competitive level seem to be related to the ability to produce higher levels of forces on shorter time frames. Accordingly, despite no differences were observed in peak forces (both absolute and relative) between PRO and SEMI-PRO players, the former group was characterized by greater levels of power (both absolute and relative) and greater peak velocities during the ECC phase. These abilities may play a key role during the futsal specific movements and contribute to be more efficient during the match-play from a physical point of view. From an applied perspective, the present results suggest that: 1) futsal players may benefit from performing ECC-based and plyometric exercises, thus producing high levels of force within short time periods during the training sessions; and 2) a more comprehensive analysis of CMJ is recommended to evaluate and compare players from different competitive levels.

When comparing vertical jump ability amongst playing positions (i.e., D, W, and P), non-significant trivial-to-small differences were found in all CMJ metrics, which suggests that vertical jump seems not to differentiate players from different positions. These results support a previous study (187), that compared the CMJ height among goalkeepers, D, W, and P, and expand current knowledge by reporting no differences in a multitude of complementary jump-land variables. To some extent, the similar performances observed in all CMJ metrics among on-court players could be explained by the fact that, in futsal, playing positions are not as clearly define as in other indoor sports (e.g., basketball (190) or handball (191)). In fact, in futsal, tactical behaviours usually require players to adopt multiple playing positions during the same match (depending on the strategic plan of the team) which contributes to players having more similar physical performance profiles (188). Future studies should further investigate which are the most key determinants factors (e.g., technical-tactical, physical, and anthropometrical characteristics) for player´s position in futsal.

9.5. LIMITATIONS

This study is limited by the fact that CMJ data were collected only at the end of the Pre_{se} period (i.e., Sep), which does not allow us to conclude whether similar results would be obtained during the most crucial moments of the season (i.e., In_{se}). Moreover, when dividing the sample into playing position, a small sample size was analysed in each group, which may have precluded us from identifying clear between-group differences. Lastly, all the subjects competed in Spain and the results of this study should not be expand to other populations. Future research should incorporate more physical assessments, such as sprint, COD, isometric mid-tight pull, and strength deficit calculations to better characterize PRO and SEMI-PRO players’ neuromuscular performance.

9.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In conclusion, PRO players presented some superior ECC capacity, as seen by the deeper COM displacement, the greater absolute and relative ECC peak power, and the highest ECC peak velocity when compared to SEMI-PRO players. By contrast, no significant differences were observed in any other CMJ variable. Lastly, non-significant differences were found amongst playing positions (i.e., D, W, and P) in futsal players, irrespective of the competitive level.

From an applied perspective, based on the present results, futsal S&Cc are advised to incorporate plyometric and ECC-overload exercises during the training sessions, as ECC capabilities during vertical jump seem to discriminate between PRO and SEMI-PRO players. In addition, a more thorough analysis of the CMJ is recommended as neuromuscular changes that may exist, might not be expressed by CMJ_{height} alone. Finally, players' position should not be defined taking into consideration the CMJs variables in futsal.

X – STUDY 6

X. STUDY 6

CHANGES IN NEUROMUSCULAR PERFORMANCE DURING PRE AND EARLY COMPETITIVE SEASON IN ELITE FUTSAL PLAYERS

10.1. INTRODUCTION

Players´ physical capacities (i.e., muscular strength and power, speed, agility, aerobic and anaerobic fitness) play an important role in futsal match-play (61). This team-sport is intermittent by nature and is characterized by alternating low- to high- intensity actions, and by the large number of ACC, DEC, and COD (24, 133). In addition, the total training and match-play stress imposed on futsal players, may vary during different periods of the season (17). For this reason, monitoring training and competition loads, and players' performance is common practice as reported by most practitioners in this sport (192).

Due to the long (and periodically match-congested) season in futsal, regularly assessing players' physical capacities is important as it allows coaches and sport scientists to make more informed decisions about specific training and REC needs. In this context, Ribeiro et al. (42) recommended that vertical jump testing (i.e., CMJ) should be conducted as it may help understand players' neuromuscular readiness to compete which has implications for their match performance and, consequently, for the final team result. However, it is important to consider that CMJ_{height} may not be sensitive enough to detect changes in stretch-shortening cycle performance or the contractile system function since evidence indicates that athletes may change their movement strategy to maintain (or even increase) jump height (40, 66, 67, 69). For example, in elite futsal players, Spyrou et al. (69) found that after a prolonged period of reduced training CMJ_{height} was not impaired, but specific Ecc and landing phase metrics were significantly altered. Therefore, a more comprehensive kinetic analysis of the CMJ force-time curve and its derivative impulse, power, velocity, displacement metrics could enhance the detection of positive or negative changes in athlete neuromuscular performance (60). Nevertheless, evidence describing how these CMJ metrics fluctuate across and within different phases of the season (e.g., Pre$_{se}$ versus In$_{se}$) is still scarce and thus, more research on this topic is warranted.

On the other hand, studies (67, 70, 193, 194) from different team-sports have demonstrated that neuromuscular performance, such as sprinting and jumping ability, tends to be maintained or decrease In$_{se}$ when compared to post Pre$_{se}$ but few investigations have specifically evaluated this in futsal players (48, 52, 75, 77, 195). For instance, Oliveira et al. (77) observed that repeated sprint ability was maintained from post Pre$_{se}$ to the middle of the In$_{se}$. Another study, in a sample of Brazilian futsal players noted improved performance in the Yo-Yo Intermittent Recovery Level 2 and squat jump tests following a 4-week Pre$_{se}$ period (52). However, the potential variation in a range of CMJ metrics during Pre$_{se}$ and early In$_{se}$ has not been studied in elite futsal players.

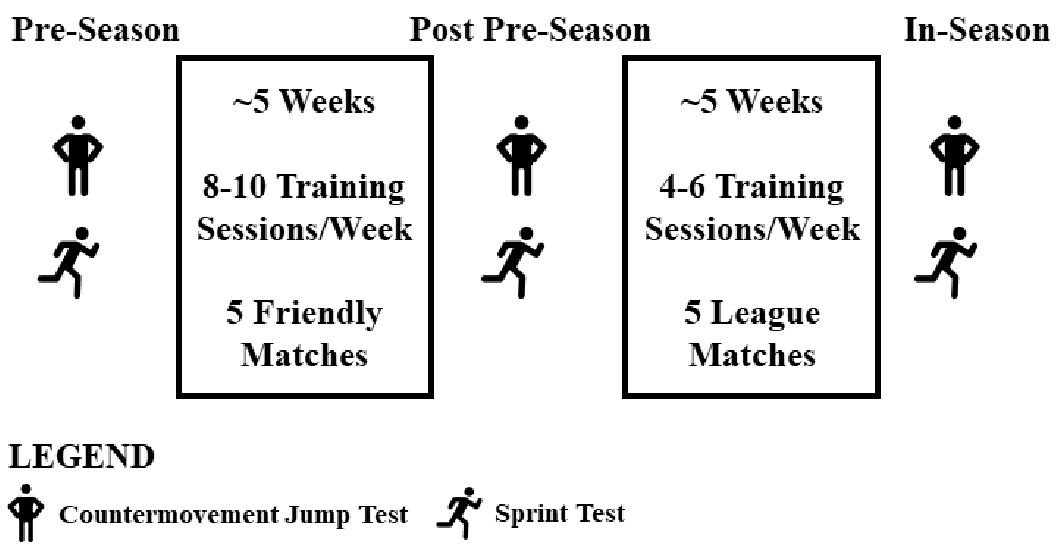
The present study aimed to investigate the fluctuations in neuromuscular performance (i.e., sprinting and jumping ability) across the initial 10 weeks of the season (including Pre$_{se}$ and In$_{se}$) in a sample of elite futsal players. It was hypothesized that performance would increase during Pre$_{se}$ and then, due to the demands of competition, be maintained or slightly decrease during the early In$_{se}$ period.

10.2. METHODS

10.2.1. Study Design

This descriptive study was designed to assess the neuromuscular performance fluctuations (i.e., sprint time and CMJ jump-landing metrics) of PRO male futsal players. The participants competed on LNFS (1st Division of Spain), during the season 2019-2020. The testing procedures were carried out at the beginning of Pre$_{se}$ (July 30th), post Pre$_{se}$ (Sep 10th), and after the first month of the competitive season (In$_{se}$) (October [Oct] 14th) (Figure 1). The players completed the same standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., two sub-maximal attempts in all tested exercises). All evaluations were completed in the team's facilities and performed following the same order (vertical jump and then sprint test). Each trial was separated by a 1 min rest interval, and 3 min were allowed between tests. The Pre_{se} evaluation was performed in the morning, at the beginning of the team´s 1st training session (after off-season period), and all the other assessments were conducted in the morning after a REC session day (i.e., Match Day +3) in order to minimize the potential influence of acute or residual fatigue induced by match-play on performance.

Figure 8 Representation of the study design.



10.2.2. Participants

Eleven players (age: 28.0 ± 5.7 years old, body mass: 73.9 ± 8.0 kg, height: 1.79 ± 0.06 m) from a PRO futsal team participated in this study. Athletes who did not complete all the assessments due to injuries were not included in the analysis. By signing a PRO contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Ethics Committee and conducted according to the Declaration of Helsinki.

10.2.3. Procedures

Vertical Jump Test: Athletes performed a CMJ test on a portable force platform (Kistler 9286BA, Kistler Group, Winterthur, Switzerland). All data was exported and analyzed with proprietary software (ForceDecks, Vald Performance, Brisbane, Australia). Athletes were instructed to place hands on the hips and perform a rapid downward movement followed by a rapid extension of the lower-limbs and to jump as high as possible and land on the platform. No other instructions were given regarding landing technique or and countermovement depth – which was self-selected. Players performed two maximal trials with 1 min rest (ICC: = 0.87, CV: = 6.5%). The CMJ_{height} was derived from impulse-momentum equation (196), and the following additional CMJ jump-landing variables were analyzed: (RSI_{mod}), ECC and CON power, force, velocity, duration, ECC Dec RFD, COM displacement, and landing peak force. The mean data of the two jumps used for analysis to reduce the random error (197).

Sprint Test: Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy), were positioned at the starting line and at 10 m. Players started from a standing position, 0.3 m behind the starting line and, when ready (without an investigator's signal), performed a maximal all-out linear sprint effort twice, with a 1 min rest (ICC = 0.85, CV: = 2.4%). The fastest time was considered for analysis. All athletes performed the test using the regular futsal shoes.….

10.2.4. Statistical Analysis

Data are presented as mean ± standard deviation. Statistical analysis was performed using a statistical package (Jamovi, 2020; Version 1.8). One-way repeated measures ANOVA was used with Post-hoc pairwise comparisons conducted. Cohen's ESs with 95% CI were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and very large (>2.0-4.0) (173). Significance level was set at $p \leq 0.05$.

10.3. RESULTS

Table 1 depicts the data for the CMJ kinetic variables analyzed. Significant and moderate-large increases were found in RSI_{mod} ($p = 0.011$; ES = 0.60), particularly, when comparing Pre_{se} to post Pre_{se} ($p = 0.005$; ES = 1.26; 95% CI = 0.44-2.05). Considering the downward ("ECC") phase, a significant and moderately higher peak force ($p = 0.011$; ES = 0.65) was found post Pre_{se} when compared to Pre_{se}

(p = 0.039; ES = 0.87; 95% CI = 0.15-1.55). Dec RFD (p = 0.008; ES = 0.60) significantly increased from Pre_{se} to post Pre_{se} (p = 0.044; ES = 0.84; 95% CI = 0.13-1.52) and In_{se} (p = 0.019; ES = 0.99; 95% CI = 0.25-1.71). ECC duration (p = 0.04; ES = 0.89) significantly decreased when comparing In_{se} to Pre_{se} (p = 0.009; ES = -1.13; 95% CI = -1.89- -0.35).

In the upward ("CON") phase, a significant and moderately higher peak force (p = 0.030; ES = 0.45) was found post Pre_{se} when compared to Pre_{se} (p = 0.033; ES = 0.90; 95% CI = 0.18-1.59). A significant time effect was found for landing peak force (p = 0.012; ES = 0.68); however, non-significant and small-moderate changes were detected within periods. Non-significant and small-trivial changes were observed in all other analyzed variables.

Figure 2 presents the group and individual data for sprint performance across the first 10 weeks of the season. A significant time interaction was found for sprint time (p = 0.038; ES = 0.58); however, non-significant and small-moderate changes were detected in sprint time when comparing Pre_{se} to post Pre_{se} (p = 0.177; ES = -0.58; 95% CI = -1.21-0.06), and In_{se} (p = 0.821; ES = 0.18; 95% CI = -0.41-0.77), and post Pre_{se} to In_{se} (p = 0.073; ES = 0.75; 95% CI = 0.06-1.41).

Figure 9 Sprint time data between the different phases of the season.

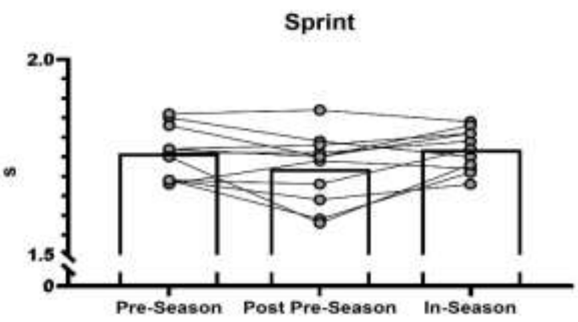


Table 10 . Description of countermovement jump kinetic variables amongst different periods.

Variables	*Units*	*Pre-Season*	*Post Pre-Season*	*In-Season*	*p value*	*Pre-Season vs Post Pre-Season*		*Post Pre-Season vs In-Season*		*Pre-Season vs In-Season*	
						p	*ES*	*p*	*ES*	*p*	*ES*
CMJ $_{height}$	cm	37.3 ± 4.5	37.8 ± 5.2	37.1 ± 4.2	0.830	0.861	0.15	0.806	-0.19	0.994	-0.03
RSI $_{modified}$	**m/sec**	**0.49 ± 0.10**	**0.54 ± 0.09**	**0.54 ± 0.07**	**0.011***	**0.005***	**1.26**	1.000	0.00	0.102	0.69
ECCENTRIC ("DOWNWARD") PHASE											
Peak Power	W	1334 ± 511	1546 ± 378	1445 ± 323	0.158	0.120	0.66	0.479	-0.36	0.682	0.25
Peak Force	**N**	**1669 ± 354**	**1877 ± 272**	**1853 ± 248**	**0.011***	**0.039***	**0.87**	0.896	-0.13	0.082	0.73
Peak Velocity	m/s	-1.25 ± 0.28	-1.38 ± 0.17	-1.31 ± 0.17	0.107	0.113	-0.67	0.307	0.47	0.636	-0.27
Dec RFD	**N/s**	**6230 ± 2480**	**7778 ± 2516**	**7780 ± 2562**	**0.008***	**0.044***	**0.84**	1.000	0.00	**0.019***	**0.99**
Duration	**ms**	**507 ± 61**	**479 ± 49**	**454 ± 41**	**0.004***	0.237	-0.52	0.104	-0.68	**0.009***	**-1.13**
COM Displacement	cm	32.8 ± 3.1	33.1 ± 2.5	30.9 ± 3.8	0.075	0.960	-0.08	0.062	0.78	0.276	0.49
CONCENTRIC ("UPWARD") PHASE											
Peak Power	W	3871 ± 604	4017 ± 618	4050 ± 559	0.065	0.184	0.57	0.827	0.17	0.182	0.58
Peak Force	**N**	**1802 ± 228**	**1920 ± 251**	**1895 ± 224**	**0.030***	**0.033***	**0.90**	0.849	-0.16	0.144	0.62
Peak Velocity	m/s	2.80 ± 0.14	2.82 ± 0.17	2.81 ± 0.15	0.822	0.799	0.19	0.859	-0.15	0.992	0.03
Duration	ms	274 ± 64	250 ± 22	241 ± 24	0.181	0.514	-0.34	0.085	-0.72	0.321	-0.46
LANDING PHASE											
Peak Force	**N**	**5779 ± 1756**	**7371 ± 2463**	**6889 ± 1789**	**0.012***	0.056	0.80	0.536	-0.33	0.057	0.80

Values presented as mean ± standard deviation.

**p* <0.05; significant differences analyzed by One-Way Repeated Measures ANOVA.

CI: confidence interval; COM: center of mass; Dec: Deceleration; ES: effect size; RFD: rate of force development; RSI: Reactive Strength Index

10.4. DISCUSSION

The purpose of this study was to investigate potential changes in neuromuscular performance in elite futsal players during the first 10 weeks of the season (i.e., Pre_{se} and early In_{se}). The main findings were that: 1) jump height did not change during the Pre_{se} and in the early competition season; 2) improvements in specific CMJ kinetic variables (i.e., RSI_{mod}, ECC peak force, ECC Dec RFD and CON peak force) were observed post Pre_{se} which indicated an enhanced neuromuscular status; 3) positive changes were also found in ECC Dec RFD and ECC duration when comparing In_{se} to Pre_{se}; and 4) a significant time interaction was found in sprint time (that improved post Pre_{se} and deteriorated in the early competitive season; however, changes between periods were small and non-significant.

Regarding vertical jump performance, several CMJ metrics (i.e., RSI_{mod}, ECC peak force, ECC Dec RFD, ECC duration, and CON peak force) improved from Pre_{se} to early competitive season (In_{se}). Of note, jump height was not altered during the first 10 weeks of the season while specific CMJ metrics significantly changed post Pre_{se} and In_{se}. Similar results have been observed in other team-sports in the sense that meaningful alterations in jump height were not detected in response to loading or unloading, whereas a more thorough kinetic analysis of the CMJ revealed significant changes in neuromuscular function (40, 66-69, 198). For example, in elite rugby players Lonergan et al (198) noted significant improvements in a number of CMJ variables such as CON duration, countermovement depth, CON impulse-100ms, CON RFD, ECC Dec RFD, RSI_{mod}, and flight time-contraction time (FT-CT) comparing the start and the end of the season. Regarding the current study, in the early In_{se} period, further but non-significant improvements were noted in ECC Dec RFD, ECC and CON duration, COM displacement. These results provide additional evidence that specific CMJ kinetic variables may be more sensitive than CMJ_{height} to detect changes in stretch-shortening musculotendinous or neuromuscular function. Furthermore, it is important to note that, across the two phases, the kinetic or "strategy" variables do not all follow the same pattern with respect to the magnitude and timing of change. For example, there was a significant large RSI_{mod} improvement during Pre_{se}, but the variable was stable during the early In_{se} period. In contrast, ECC duration showed small to moderate improvements across both phases with these changes only achieving significance (relative to Pre_{se}) in the In_{se} assessment. This highlights the potential value of examining the component durations of a composite variable/indexes such as RSI_{mod} when monitoring short-term chronic adaptations. The "uncoupling" of trends across variables might also reflect a differential time course of response to loading and dissimilar loading patterns during Pre_{se} versus In_{se}. Cohen et al (66) previously noted such a pattern with respect to detraining, whereby differing durations and type of chronic unloading were associated with divergent profiles of change in CMJ kinetics. A thorough kinetic analysis of the CMJ might, therefore, provide sport practitioners with valuable information regarding athlete status and adaptations that may not manifest in jump height. It is also important to be aware that kinetic variables may differ in their response and sensitivity to loading, warranting exploration of trends within their sport and athlete cohort.

While the overall time interaction for sprint performance was significant, non-significant changes were detected when comparing the different phases. Specifically, players were faster after the Pre_{se} but performance deteriorated during early In_{se}, which aligns with previous studies (77, 194, 199, 200). For example, Arcos et al. (199) found non-significant improvements in ACC (5 m) and sprint (15 m) time In_{se} compared to Pre_{se} in soccer players. A study in male PRO players found a negative effect of a 9-week Pre_{se} conditioning program on sprint performance (200). Conversely, also in PRO soccer players, Fessi et al. (193) reported significantly faster sprinting times post Pre_{se} when compared to both Pre_{se} and In_{se}. These inconsistencies could be explained by the different training programs carried out (the specifics of which were not described in these studies), the players′ profiles, such as chronological and training age or the competitive level, game congestion, and timing of tests relative to the game or TL. The present results suggest, from an applied perspective, that S&Cc should frequently assess sprint capacity within the training sessions (using automatic timing systems) to facilitate the prescription of tailored-made training programs, with adequate sprint exposure and REC.

10.5. LIMITATIONS

This study is limited by its small sample size. Nevertheless, it is important to note that futsal teams are composed of 12 to 14 athletes, from which 11 (>80% of the team's players) were tested on three occasions during the first 10 weeks of the season (contemplating the Pre_{se}, post Pre_{se}, and In_{se}). Moreover, players' total training and match load, an important determinant of neuromuscular status, were not recorded during the 10-week period.

10.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In summary, the present study adds to the body of evidence demonstrating that while CMJ_{height} may not change, longitudinally positive or negative alterations in neuromuscular performance may be detected by monitoring phase-specific CMJ kinetics. Changes in RSI_{mod}, ECC peak force, Dec RFD, and duration, indicative of positive adaptations to Pre_{se} training, were observed in elite futsal players during the first 10 weeks of the season. Other CMJ metrics such as ECC peak power and velocity, COM displacement, CON peak power, velocity, and duration, and landing peak force showed small positive but non-significant changes across the studied periods. Regarding sprint performance, a significant time interaction was found in sprint time but the post-hoc analysis was unable to decipher meaningful differences between the phases of the season as changes were small and non-significant.

Based on the current data, S&Cc should implement a thorough analysis of the players´ CMJ kinetics, as neuromuscular adaptations that may occur, might not be expressed by changes in CMJ_{height}. Metrics, such as RSI_{mod}, ECC and CON peak force, ECC duration, and Dec RFD may be more sensitive to neuromuscular chronic adaptations of futsal players to on- and off-court training, and competition. Finally, sport practitioners are advised to use a broad speed-power assessment during season to evaluate player´s physical adaptations and adjust the training session accordingly.

XI – STUDY 7

XI. STUDY 7

NEUROMUSCULAR PERFORMANCE CHANGES IN ELITE FUTSAL PLAYERS OVER A COMPETITIVE SEASON

11.1. INTRODUCTION

Futsal is a high-intensity intermittent indoor sport, with high physical, technical, and tactical demands (17, 61). The typical competitive season consists of ~50 regular matches including national (i.e., League and Cup) and international (i.e., European club tournaments and National Team) competitions over a span of ~7.5 months, with a frequency of 1 to 3 games per week. During a single match, futsal players cover a total distance of ~4000 m, of which ~675 m are spent running (12 – 18 km·h^{-1}) and ~130 m sprinting (>18 km·h^{-1}), perform ~70 high intensity ACC and DEC and complete ~170 COD actions (24, 133). In addition, they usually complete daily or twice-a-day sessions for games' preparation, covering as much as ~10 km (on average) at high and very-high intensities during a typical weekly microcycle (62). Thus, a PRO futsal season imposes a large physiological and mechanical stress on athletes (17, 61). For this reason, training and competition loads can lead to not only acute neuromuscular fatigue (i.e., failure of the musculoskeletal system to maintain the required force or power output) (63), but also residual (i.e., 24 – 72 h following exercise (64)), and potentially chronic fatigue (i.e., overtraining syndrome) (65), throughout the season, if appropriate individual tailor-made training programs (e.g., adjusting REC times or limiting on-court weekly distance) are not considered.

Neuromuscular performance monitoring (i.e., through jump, sprint testing, etc.) is often used as a practical tool to periodically evaluate the response to the training and competition stress that team-sport athletes are exposed to across the season (39, 40). For example, decreases in CMJ performance (i.e., jump height) have been observed after soccer and rugby league matches (201, 202). However, a number of studies (66-68) have shown that a more comprehensive analysis of kinetic variables during the jump-land cycle is needed to detect neuromuscular impairments associated with acute or residual fatigue, permitted when the test is performed with force platforms. Similarly, adaptive responses following periods of training (40, 59) or detraining (66, 69) may require a thorough analysis of selected CMJ metrics to identify alterations in neuromuscular status during the season that are not detected by monitoring jump height alone.

Several investigations (67, 68, 70-74) have examined neuromuscular performance at several timepoints during the sports season and shown that, overall, physical abilities tend to be maintained or decrease across the season. Legg et al. (72) detected trivial declines (effect size [ES] = -0.18) in CMJ performance and jump-land cycle during the competitive period in elite female basketball players. Nonetheless, there is also evidence demonstrating that physical capacities can be enhanced during the competitive period in team-sports (203). For example, Gonzalez et al. (203) observed, in a sample of elite basketball players, that starters improved vertical jump power, quickness, and reaction time 17.15%, 0.29%, and 5.66% more, respectively, than non-starters during the season. The variability in findings across these studies may be attributed to differences in the characteristics or demands of the sport, the level of the competition, the congestion of the competitive calendar (i.e., different number of matches per week), age (e.g. youth-amateur vs experienced) or contextual factors (e.g., player role: starters vs non-starters) (67, 68, 74, 203). Regarding futsal, few studies (75-77) have investigated potential changes in physical capacities across the season. Particularly, in PRO futsal players, the influence of training and competition stress on sprint, horizontal and vertical jump performance and on CMJ kinetic variables (assessed multiple times across the competitive period) has not been examined.

Based on the above considerations, the aim of this study was to examine potential changes in speed-power related outputs (i.e., sprint speed, SLJ distance and vertical jump height) and CMJ kinetic variables (derived from the ECC, CON, and landing phases) across the season in elite futsal players. Due to the prolonged and congested schedule in PRO futsal, we hypothesized that performance across all metrics would decline as the season progressed.

11.2. METHODS

11.2.1. Study Design

This longitudinal study was designed to track the neuromuscular performance (i.e., sprint time, CMJ kinetic variables, and SLJ distance) of elite male futsal players. The participants competed on LNFS (1st Division of Spain) and UEFA Futsal Champion League over the 2019-2020 season, which spanned from August to March due to the COVID-19 restrictions imposed in Spain. The testing procedures were performed regularly during the season, at four time-points (i.e., Sep, Oct, December [Dece] and January [Jan]) (Figure 10). In each session, all players completed the same standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., sub-maximal attempts in all tested exercises). The regular and congested weekly in-season training and game schedule is presented in Table 11. The evaluations were completed in the team´s facilities during regular weeks (i.e., one game per week), three days after a match, in the following order: vertical and SLJ jump and sprint test. Each trial was separated by a 1 min rest interval, and 3 min were allowed between successive tests.

Figure 10 Representation of the study design.

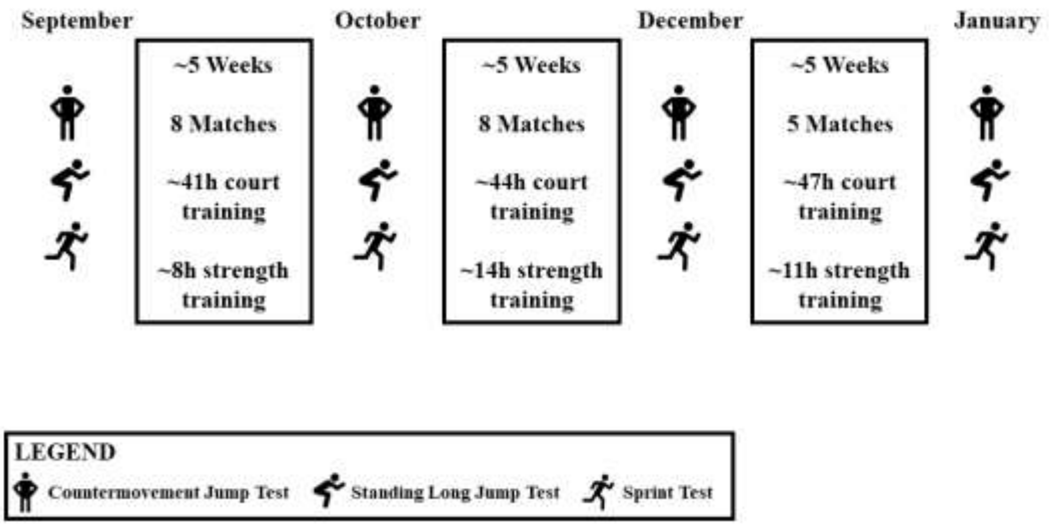


Table 11 Typically normal and congested weekly schedule during the competitive period.

Normal Week (1 Game)							
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**
AM	Recovery	Power-Strength Training	Power-Strength Training	Tec-Tact Training	Tec-Tact Training	Tec-Tact Training	Game
PM		Tec-Tact Training	Tec-Tact Training				
Congested Week (>2 Games)							
Day	**1**	**2**	**3**	**4**	**5**	**6**	**7**
AM	Power-Strength Training	Tec-Tact Training	Game	Recovery	Tec-Tact Training	Tec-Tact Training	Game
PM	Tec-Tact Training						

Tac: Tactical training; Tec: technical training.

11.2.2. Participants

Twelve players (age: 26.7 ± 3.1 years old, body mass: 76.7 ± 6.3 kg, height: 1.79 ± 0.06 m, body fat: 9.9 ± 1.2%) from an elite futsal team volunteered to take part in the study. Athletes who did not complete more than one assessment due to injury (i.e., as determined by the team's medical team that was responsible for the evaluation and recording of injuries according to the consensus statement of injuries in soccer (204), previously used in futsal (181)) were not included in the analysis. Two players did not meet these inclusion criteria; hence, 10 players were finally included in the study. By signing a PRO contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Ethics Committee of the Catholic University of Murcia (UCAM) and were conducted according to the Declaration of Helsinki.

11.2.3. Procedures

Sprint Test: Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy), were positioned at the starting line and at 10-m. Players started from a staggered position, 0.3-m behind the starting line and performed a maximal all-out linear sprint twice, with a 1-min rest (ICC = 0.71, CV: = 4.5%). The fastest time was considered for analysis. All athletes performed the test on a wooden surface using regular futsal shoes.

Horizontal Jump Test: Athletes performed a SLJ, positioning their feet shoulder-width apart behind the starting line and the arms at the side of the body. A countermovement with arm swing was allowed before jumping. They were instructed to jump as far as possible, in the horizontal direction, and the longest distance was recorded for analysis. Players performed a maximal effort three times with a 1-min rest (ICC: = 0.92, CV: = 3.8%). Athletes were required to land with both feet simultaneously and, in case they fell forward or backward or touched the ground with one hand, the trial was considered invalid and repeated. The distance between the starting point and the heel of the rear foot measured by a tape to the nearest 1 cm was considered.

Vertical Jump Test: Athletes performed a CMJ on a portable force platform (Kistler 9286BA Kistler Group, Winterthur, Switzerland). Data were exported, and analyzed using proprietary software (Python v.3.8.3). Athletes were required to perform a downward movement followed by a complete, rapid extension of the lower-limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement and athletes were directed to jump as high as possible and land close to the take-off point. They executed three maximal trials with 1-min rest between each (ICC: = 0.97, CV: = 5.9%). Jump height and multiple kinetic variables (i.e., ECC and CON peak power and velocity, duration, COM displacement, landing peak force, and RFD to peak force) from the best jump trial (according to the highest jump height) were retained for analysis.

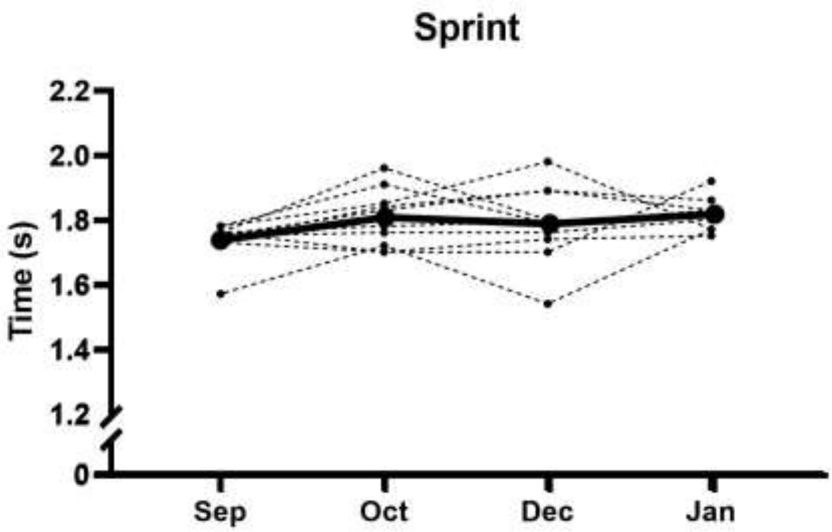
11.2.4. Statistical Analysis

Data are presented as means ± standard deviations (SD). Statistical analysis was performed using a statistical package (Jamovi, 2020; Version 1.8). One-way repeated measures ANOVA was used, and Post-hoc pairwise comparisons conducted. Cohen's ESs with 95% confidence intervals (95% CI) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and very large (>2.0-4.0) (173). Significance level was set at $p \leq 0.05$.

11.3. RESULTS

Figure 11 displays the group and individual data for sprint performance during the competitive period. A non-significant but moderate time effect was observed (p = 0.155; ES = 1.03). Specifically, the following results were found when comparing consecutive measurements: Sep – Oct (p = 0.240; mean difference [Dif_{mean}] = 3.9%; ES = 0.81; 95% CI: [0.07 – 1.52]), Oct – Dec (p = 1.00; Dif_{mean} = -1.1%; ES = -0.18; 95% CI: [-0.83 – 0.47]), Dec – Jan (p = 0.933; Dif_{mean} = 2.2%; ES = 0.20; 95% CI: [-0.50 – 0.90]), Sep – Jan (p = 0.081; Dif_{mean} = 4.7%; ES = 1.05; 95%CI: [0.20 – 1.85]).

Figure 11 Sprint time data during the season. Bars represent mean values, and symbols and lines represent individual changes.

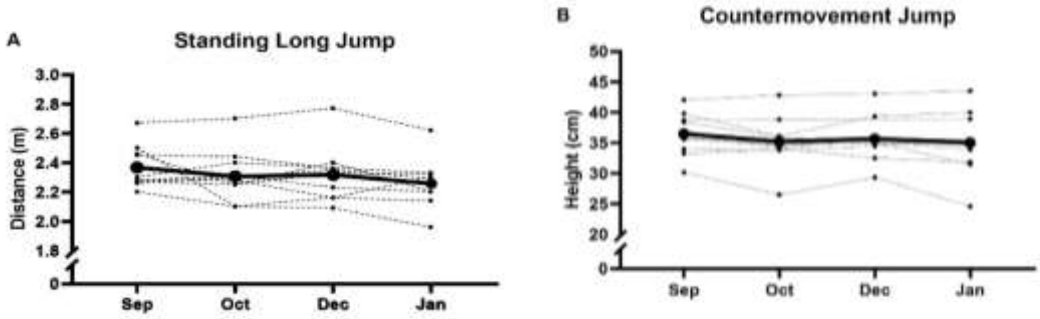


Dec: December; Jan: January; Oct: October; Sep: September

Figure 12 presents the group and individual data for vertical and SLJ performance, and Table 12 depicts the data for selected CMJ kinetic variables. Regarding SLJ distance, a non-significant but moderate time effect was detected (p = 0.164; ES = 1.03). In detail, the following results were obtained: Sep – Oct (p = 0.518; Dif_{mean} = -2.2%; ES = -0.36; 95% CI: [-0.99 – 0.28]), Oct – Dec (p = 0.856; Dif_{mean} = 0.6%; ES = 0.14; 95% CI: [-0.51 – 0.79]), Dec – Jan (p = 0.463; Dif_{mean} = -2.3%; ES = -0.54; 95% CI: [-1.27 – 0.21]), and Sep – Jan (p = 0.376; Dif_{mean} = -3.9%; ES = -0.54; 95% CI: [-1.23 – 0.17]).

Considering vertical jump, a significant difference was found only in CON peak power (p = 0.040; ES = 1.24), when comparing Sep to Oct (p = 0.013; Dif_{mean} -3.1%; ES = -1.26; 95% CI: [-2.09 – -0.40]). Moreover, a non-significant and moderate time effect was found for jump height (p = 0.175; ES = 1.00). Specifically, pairwise comparisons displayed the following results: Sep – Oct (p = 0.300; Dif_{mean} = -3.6%; ES = -0.72; 95% CI: [-1.40 – -0.00]), Oct – Dec (p = 0.595; Dif_{mean} = 2.6%; ES = 0.53; 95% CI: [-0.17 – 1.22]), Dec – Jan (p = 0.503; Dif_{mean} = -3.5%; ES = -0.51; 95% CI: [-1.24 – 0.23]), and Sep – Jan (p = 0.479; Dif_{mean} = -5.1%; ES = -0.48; 95% CI: [-1.17 – 0.21]). In the rest of the analyzed variables during CMJ CON ("upward") phase, no significant changes were observed (peak velocity: p = 0.142; ES = 1.06; duration: p = 0.938; ES = 0.20). In the ECC ("downward") phase, non-significant trivial to moderate decreases were observed in peak power (p = 0.529; ES = 0.78), peak velocity (p = 0.238; ES = 0.90), duration (p = 0.316; ES = 0.84) and COM displacement (p = 0.554; ES = 0.62). In the landing phase, there were non-significant and small to moderate changes in peak force (p = 0.188; ES = 1.00) and RFD to peak force (p = 0.681; ES = 0.50).

Figure 12 **A)** Standing long jump distance data. Bars represent mean values, and symbols and lines represent individual changes. **B)** Vertical jump height data. Bars represent mean values, and symbols and lines represent individual changes.



Dec: December; Jan: January; Oct: October; Sep: September

Table 12: Description of horizontal and countermovement jump kinematic and kinetic variables during the season.

							Split periods						Total period	
							Sept–Oct		Oct–Dec		Dec–Jan		Sept–Jan	
Variables	Units	Sept	Oct	Dec	Jan	*p*	%	ES	%	ES	%	ES	%	ES
SLJ	cm	2.37 ± 0.14	2.31 ± 0.17	2.32 ± 0.20	2.26 ± 0.17	0.164	−2.2	−0.36	0.6	0.14	−2.3	−0.54	−3.9	−0.54
CMJ_{Height}	cm	36.5 ± 3.48	35.2 ± 4.12	35.6 ± 3.87	35.0 ± 5.54	0.175	−3.6	−0.72	2.6	0.53	−3.5	−0.51	−5.1	−0.48
$RSI_{modified}$	m/s	0.51 ± 0.09	0.47 ± 0.10	0.48 ± 0.08	0.50 ± 0.12	0.126	−7.9	−0.71	7.4	0.46	0.0	0.03	−4.6	−0.28
Eccentric ("downward") phase														
Peak power	W/kg	−18.1 ± 4.63	−18.1 ± 6.24	−17.2 ± 4.79	−20.1 ± 5.88	0.529	−1.3	0.04	5.2	−0.10	11.7	−0.65	5.2	−0.48
Peak velocity	m/s	−1.28 ± 0.15	−1.21 ± 0.25	−1.30 ± 0.20	−1.34 ± 0.17	0.238	−5.5	0.34	13.0	−0.62	2.3	−0.09	3.0	−0.32
Dec duration	ms	165 ± 35.0	176 ± 43.0	171 ± 36.0	163 ± 30.0	0.316	6.5	0.38	−3.7	−0.31	2.1	0.16	4.3	0.23
COM displacement	cm	31.3 ± 4.11	30.1 ± 3.57	32.6 ± 4.06	30.5 ± 3.18	0.554	−3.4	−0.39	7.6	0.62	−2.6	−0.36	−0.8	−0.00
Concentric ("upward") phase														
Peak power	W/kg	54.7 ± 5.24	53.0 ± 5.55	51.9 ± 4.61	52.9 ± 6.67	**0.040**‡	−3.1	−1.26	−0.4	−0.34	−1.0	0.16	−4.8	−0.93
Peak velocity	m/s	2.80 ± 0.12	2.76 ± 0.14	2.78 ± 0.12	2.76 ± 0.18	0.142	−1.6	−0.81	1.3	0.74	−1.3	−0.49	−1.7	−0.46
Duration	ms	259 ± 27.0	259 ± 28.0	266 ± 27.0	259 ± 26.0	0.938	0.1	−0.00	1.9	0.10	0.5	0.11	2.2	0.16
Landing phase														
Peak force	N/kg	105 ± 28.7	104 ± 41.3	92.4 ± 19.5	89.1 ± 17.4	0.188	−1.0	−0.02	−6.3	−0.43	0.5	−0.05	−18.1	−0.70
RFD to peak force§	N/s/kg	3,721 ± 3,003	3,398 ± 2,294	3,685 ± 2,884	2,784 ± 1948	0.681	−3.4	−0.25	3.3	0.08	9.0	−0.09	−15.8	−0.50

Values presented as mean ± SD.

*$p < 0.05$; significant differences analyzed by One-Way Repeated Measures ANOVA.

CI: confidence interval; COM: center of mass; Decel: deceleration; RFD: rate of force development; RSI: reactive strength index; SD: standard deviation; SLJ: standing long jump.

[a]RFD to Peak Force: average RFD calculated from landing [time 1] to landing peak force [time 2]. Impulse, force, RFD and power variables are expressed relative bodyweight

11.4. DISCUSSION

The purpose of this study was to examine potential fluctuations in neuromuscular performance (i.e., sprint time, vertical jump height and selected kinetic variables, and SLJ distance) across the season in elite futsal players. Our main findings were: 1) physical abilities (i.e., sprint time, SLJ distance, and vertical jump height) displayed non-significant but gradual declines throughout the competitive period; 2) CON peak power was the only CMJ kinetic variable that decreased significantly; and 3) all other CMJ metrics considering the three phases (i.e., ECC, CON, and landing) showed non-significant small-to-moderate changes.

It appears that elite futsal players were not able to improve their sprinting ability throughout the competitive period (they sustained a gradual non-significant decline), aligning with previous findings in team-sports athletes (77, 194, 199). For instance, Oliveira et al. (77) observed that repeated sprint ability was maintained during in-season in elite Brazilian futsal players. In another study, Haugen et al. (194) found that sprint performance was superior at the off-season compared to in-season and Pre_{se}. This phenomenon could be related to the concurrent training effect between power and endurance adaptations across the season, as well as the insufficient REC during congested periods (194, 205). From an applied standpoint, it is important to note that in the present study, despite not achieving statistical significance, sprint times were ~5% (ES = 1.05) higher (i.e., indicating lower performance) in Jan when compared to Sep, suggestive of a gradual decrease in maximal sprinting ability across the season. Periodic assessment of this quality during the competitive period could identify potential neuromuscular performance impairments, allowing individualized power-speed oriented training prescription according to a player's competition and training cumulative load and response thereof.

Moderate but non-significant decrements in jumping ability were observed throughout the season. Mean CMJ_{height}, and SLJ distance values were, on average, 5.1% (ES = -0.48) and 3.9% (ES = -0.54) lower, respectively, in Jan when compared to Sep aligning with findings in other studies in team-sports (68, 70, 72, 74). For example, Kipp et al. (68) observed that while team-average jump height did not change over the course of the season, in individual players, greater competition volume was associated with decreased CMJ_{height} in female collegiate volleyball players. In PRO ice hockey, a significant decrease in CMJ_{height} across the season was found (67). In contrast, an investigation in NBA players revealed that, in players with greater playing minutes, repetitive vertical jump power and lower body-power increased during the competitive period (203). These divergent results could be explained by the characteristics or loading demands of the sports investigated (e.g., basketball vs ice-hockey) and timing of the re-test (i.e., Pre_{se}, early season, mid-season, and late season, 36 hours after the last game vs before the start of the regular season and at the end of the regular season). In the present study, jump height had slight, steady but non-significant decreases over the season. Nevertheless, from a practical perspective, it is important to acknowledge that each athlete responds individually to the applied stress, and by identifying abnormal responses, tailored-made training strategies may then be implemented to avoid or mitigate detrimental effects.

A comprehensive kinetic analysis of the CMJ identified a significant and large (ES = 1.24) decline in CON peak power and small-moderate but non-significant effects in ECC and landing phase-specific metrics (i.e., peak power and velocity, RFD, duration, etc.), with the largest differences observed between Sep and Jan (Table 12). Significant changes in CMJ kinetic variables have been noted in studies in other team-sports athletes (67, 68). In PRO ice-hockey athletes, Gannon et al. (67) found that CON peak velocity and COM displacement decreased in the late-season when compared to the early-season. Moreover, the CON power decrements may reflect potential residual fatigue or the muscular-skeletal system that negatively affect power production capabilities as the season progresses (66). Therefore, sports practitioners, coaches, and scientist should be aware that a thorough kinetic analysis of the CMJ might provide valuable information regarding the neuromuscular status of the athletes that may not be obtained when analyzing jump height alone (40, 69). Lastly, frequent evaluations during the competitive period may allow to describe better the effects of training or competition stress on jump-landing cycle fluctuations. We also noted that while CMJ_{height} steadily decreased, ECC (i.e., peak power and velocity, duration and COM displacement) and landing (i.e., peak force and RFD to peak force) metrics showed positive trends during specific time-points of the season.

11.5. LIMITATIONS

There are limitations to this study that must be acknowledged. Firstly, the season was abbreviated due to the COVID-19 pandemic (i.e., interrupted in March 2020 and recommenced directly with play-off games in June 2020). Therefore, the duration of the competition season was 6 months of instead of the typical ~8-month season. Secondly, a small sample size was analyzed. Nevertheless, it is important to note that futsal teams are composed of only 12 – 14 players, from which 10 were tested during the season, representing >80% of the team's players. Thirdly, participant´s total playing time, which could mediate the fluctuations of the neuromuscular performance throughout the season, was not recorded. Finally, a more comprehensive testing battery (e.g., including COD tasks, unilateral and bilateral drop jumps, or maximal strength assessments) and more frequent evaluations (e.g., weekly tests), could allow to describe better the effects of training or competition stress on neuromuscular performance during the competitive period. Nevertheless, the aim of the study was to evaluate the chronic adaptations on neuromuscular performance during in-season, with tests conducted at a moment of the week (i.e., three days after competition) at which point the residual fatigue effects associated with match-play are limited (64).

11.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In summary, considering the neuromuscular performance tests and variables assessed, only CON peak power in CMJ decreased significantly across the season. However, gradual and non-significant decrements were observed in other assessments (e.g., sprint time [4.7%; ES = 1.05], SLJ distance [3.9%; ES = -0.54]) and vertical jump outcomes (e.g., CMJ_{height} [5.1%; ES = -0.48]). Other jump-landing phase cycle metrics (i.e., ECC peak power and velocity, duration, COM displacement, landing peak force and RFD to peak force) showed positive small-moderate fluctuations throughout the season. The accumulated training and game demands may preclude futsal players from increasing gross sprinting and jumping performance (such as height or power) during the competitive period.

Monitoring elite futsal players' performance is crucial not only for individual athlete care but also for the team's success. From an applied perspective, monitoring practices should consider the individual athlete's response to the match and training stress they are exposed to, in order to identify the need for adjustments to competition or TL and REC and, ultimately, to minimize potential performance decrements. Based on the current data, practitioners are encouraged to perform a broad speed-power assessment including a more thorough kinetic analysis of the CMJ as it might provide valuable information regarding the neuromuscular status of the athletes that may not be identified when monitoring jump height alone. Specifically, CON peak power should be considered a variable of interest as, in the current study, it was the only CMJ metric that decreased significantly across the season.

XII – STUDY 8

XII. STUDY 8

EFFECTS OF THE COVID-19 LOCKDOWN ON NEUROMUSCULAR PERFORMANCE AND BODY COMPOSITION IN ELITE FUTSAL PLAYERS

12.1. INTRODUCTION

Futsal is a high-intensity intermittent indoor sport, with high physical, technical, and tactical demands during match-play (1-4, 61). In competitive scenarios, futsal players have been shown to cover an average of 4,313 m during a single match, with high-intensity running corresponding to 13.7% and sprinting to 8.9% of the efforts performed (1). Moreover, players may complete ;30 sprints, in sequences of 2, 3, and 4 sprints, with 15–60 s rest intervals (3). These data highlight the importance of players having well-developed neuromuscular capabilities that enable them to successfully perform actions that require high-power outputs (e.g., sprints, jumps, and rapid COD) and cope with the high-intensity demands of competition. In this regard, jumping and sprinting ability are commonly used as monitoring tools to evaluate players' performance and fatigue levels throughout the season (39, 40, 206).

Regarding PRO futsal, recent world events have resulted in an unparalleled situation with important implications for elite players. At the beginning of 2020 (January– March), sport leagues and tournaments worldwide (e.g., European soccer and futsal national leagues or the Olympic Games) were postponed or canceled because of a novel virus: SARS-CoV-2 (COVID-19). The uncontrolled spread of the virus caused thousands of cases of respiratory problems globally leading the World Health Organization to declare COVID-19 a pandemic (78). Most European countries imposed a mandatory confinement that, among other occupations, affected PRO sports. As a consequence, athletes were forced to stay at home and were not allowed to use the team's training facilities. To face this unprecedented scenario during the in-season period, coaches and sports scientists provided several training recommendations in an attempt to minimize the detrimental effects caused by the lockdown on physical performance (79). Nevertheless, the actual effects of home confinement and long-term reduced training cannot be properly comprehended until players return to their normal activities.

According to Mujika and Padilla (207, 208), detraining is defined as the total or partial loss of anatomical, neuromuscular, and physiological adaptations due to training reduction or cessation. Training cessation refers to the partial or complete pause of a precise training plan; reduced training consists on a nonprogressive reduction of the training that may maintain or improve performance (207). On this topic, Koundorakis et al. (209) observed that after a long-term (i.e., 6 weeks) training cessation highly trained soccer players' neuromuscular responses (i.e., sprint and vertical jump) were negatively affected. Similarly, decreased ECC knee extension force, electromyographic activity of the vastus lateralis during an isometric test, and changes in type II fiber areas were reported after 2 weeks of training cessation in power athletes (210). Moreover, fiber type transitions (i.e., from fast type II to slow type I fibers) have been shown to occur after detraining in several studies (211-213). Thus, it seems that sudden decreases in TL for an extended period may be detrimental to performance, particularly in highly trained individuals. However, a situation as the one caused by the COVID-19 (which resulted in PRO athletes spending more than 60 days without adequate training, resources, and competition stimuli) is unprecedented, and therefore, its effects on athletic performance are unknown, particularly in futsal players. In fact, studies on this topic focused mainly on elite soccer. For example, an investigation with Brazilian players revealed significant decreases in CMJ and sprint (i.e., 10 and 20 m) performance after the quarantine (214). Similarly, another study (66) demonstrated that, although isolated resistance circuit and aerobic training was able to maintain CMJ_{height}, RSI, and peak CON and ECC power during the lockdown, other specific ECC (i.e., downward) and landing phase kinetic variables were significantly altered in elite soccer players. As such, additional research in neuromuscular performance components is still needed to better understand the effects of long-term training cessation.

Body composition (i.e., body mass, fat percentage, and muscle mass) is another important aspect to consider in PRO athletes as it plays a crucial role in competitive performance (215). A decrement on physical activity levels reduces energy expenditure that, in turn, may increase body fat (216). Previous research conducted with PRO soccer players found that body fat and body mass were negatively affected after the transition phase of the season (209). However, to understand the effects of an unusual and prolonged home confinement on body composition in top-level athletes (e.g., elite futsal players), further investigation is warranted.

This study aimed to investigate the effects of a 70-day reduced training period forced by the COVID-19 quarantine on speed power–related capacities (i.e., sprint acceleration, horizontal jump, and vertical jump) and body composition (i.e., body mass, body fat percentage, and muscle mass) of elite futsal players. Because of the prolonged period of specific reduced training, we hypothesized that athletic performance and body composition would be negatively affected by the lockdown period.

12.2. METHODS

12.2.1. Study Design

This pre-post quasi-experimental study aimed to investigate the changes on speed-power–related performance and body composition after the home confinement period caused by the COVID-19 pandemic. In Spain, the lockdown was announced on March 14, 2020. The pre-lockdown performance had been previously assessed on March 3, 2020, (as part of the physical testing procedures applied monthly to the futsal players during the in-season period) and the post-lockdown evaluation was conducted on May 13, 2020 (i.e., 70 days later). The pre-confinement body composition data were collected on March 2 and post-confinement assessments were conducted on May 12, 2020 (i.e., after 70 days). Pretest evaluations were completed for all players collectively, whereas, on posttest, players reported to the laboratory individually (3 players were assessed each hour, between 09:00 and 13:00 hours), according to the governmental guidelines. All players were familiarized with the testing procedures because of their regular routines in our facilities. Players completed the same standardized general warm-up protocol consisting of running based activities, dynamic stretching, core and lower-body activation exercises, followed by a test-specific warm-up (i.e., submaximal attempts in all tested exercises). Tests were performed on the following order: vertical jump, horizontal jump, and sprint-acceleration test. The 10 m sprint test was selected because futsal match activity profiles have shown that the average sprinting distance is ;10.5 m (61). Each trial was separated by a 1-minute rest interval, and 3 minutes were allowed between successive trials and tests.

During the lockdown, each player followed an individualized nutritional plan developed by the team's nutritionist and adjusted every 2 weeks. To keep pre-quarantine body composition parameters, players recorded their body mass twice per week and reported it to the team's nutritionist. The Harris-Benedict's equation (217) was used to measure energy expenditure and determine each player's energy intake (i.e., should be the same as the energy expenditure). In addition, all players completed a semi-structured maintenance training program (Table 13) comprising exercises using only the body mass as resistance (e.g., vertical and horizontal jumps, half and full squats, lunges, push-ups, etc.). Athletes were instructed to perform these exercises 2–3 times per week, completing 2 or 3 sets of 6–8 (jumps) and 10–12 (squats and lunges) repetitions. Importantly, and as shown in Table 1, despite completing the maintenance program, players experienced a considerable decline in all type of fast stretch-shortening cycle actions during the lockdown (i.e., due to the lower training intensity and frequency and to the lower exposure to jumping and other explosive actions characteristic of futsal training and match-play). All players confirmed that they did not seek any professional advice outside of the team's coaching staff nor did they follow any prescribed training by other practitioners. In this sense, during the quarantine period, athletes were considered to be on a long-term reduced training phase.

Table 13 Models of the training structure during the competitive season and the lockdown period.

	Competitive season		
Training Strategy	Resistance Training	RST	Plyometric
Exercise Type	Traditional and Ballistic	Resisted sprints	VJ-HZ
Intensity	30-70% 1RM	High	High
Volume	2-3 sets 4-8 reps	10 m 5-8 reps	2-3 sets 8-10 reps
Frequency	2 – 3 sessions·wk^{-1}		
Sport-specific Training - Official Matches	5 – 6 sessions·wk^{-1} – 1 – 2 official matches·wk^{-1}		

	Lockdown period	
Training Strategy	Resistance Training	Plyometric
Exercise Type	BW	VJ-HZ
Intensity	Low	High
Volume	2-3 sets 10-12 reps	2-3 sets 6-8 reps
Frequency	2 – 3 sessions·wk^{-1}	

BW: body weight; HIIT: high-intensity interval training; HZ: horizontal jumps; reps: repetitions; RST: resisted sprint training; VJ: vertical jumps; wk: week.

12.2.2. Participants

Players from an elite futsal team (i.e., a 12-player squad) volunteered to take part in the study. Two athletes did not complete the last assessment pre-quarantine because of minor injuries and were not included in the analysis. Therefore, 10 elite male futsal players (mean ± SD; age: 26.7 ± 3.1 years old, body mass: 76.0 ± 6.6 kg, height: 1.78 ± 0.06 m) participated in this study. Futsal players competed in the Spanish National League (LNFS) and were qualified to play the UEFA Futsal Champions League Final. Therefore, the high level of the players in this study sample can be confirmed. All athletes involved were free of injury before the quarantine. By signing a PRO contract with the club, all players provided individual written informed consent for data collection and study participation. All procedures were approved by the Catholic University of Murcia (UCAM) Ethics Committee and were conducted according to the Declaration of Helsinki.

12.2.3. Procedures

Sprint-Acceleration Test. Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy) were positioned at the starting line and at 10 m. Players started from a standing position, 0.3 m behind the starting line, and performed a maximal all-out linear sprint twice, with a 1 min rest (ICC 0.82, CV: 3.9%). Players started the test when ready, with no investigator's signal. Given the short distance (i.e., 10 m) assessed, the test could be considered to evaluate ACC capabilities because players did not achieve maximum sprinting velocity. All athletes performed the test using the regular futsal shoes and on a wooden surface. The fastest time was retained for analysis.

Horizontal Jump Test. Athletes stood with their feet shoulder-width apart behind the starting line and the arms at the side of the body. They were instructed to jump as far as possible in the horizontal direction. A countermovement with arm swing was allowed. Players performed a maximal effort 3 times with a 1- minute rest (ICC: 5 0.91, CV: 5 3.7%). Athletes were required to land with both feet simultaneously, and in case they fell forward or backward, the trial was considered invalid and repeated. The distance between the starting point and the heel of the rear foot measured by a tape to the nearest 1 cm was considered. The longer distance was recorded for analysis.

Vertical Jump Test. CMJ was used to determine the vertical jump ability. Athletes were required to perform a downward movement, followed by a complete, rapid extension of the lower limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement, and athletes were directed to jump as high as possible and land close to the take-off point. They executed 3 maximal trials with 1- minute rest (ICC: 5 0.94, CV: 5 6.0%). The CMJ was performed on a Kistler 9286BA portable force platform (Kistler Group, Winterthur, Switzerland), and the data were exported and analyzed with the software ForceDecks (Vald Performance, Brisbane, Australia) and processed using Python (v.3.8.3). Jump height and multiple kinetic variables (e.g., impulse, peak power, peak force, and velocity or RFD) (66) from the best jump trial (according to highest jump height) were retained for analysis.

Body Composition. All the assessments were completed by the same experienced evaluator (nutritionist), who had ISAK certification, in accordance with ISAK's international standards (218). Players were required to be on a fasted state, to avoid caffeine and alcohol consumption for at least 8 hours before the procedure, and to wear only the team's training shorts. Body mass was assessed using a Tanita HD-313 scale (Tanita Corporation, Tokyo, Japan) with a 150 kg capacity and accuracy to the nearest 0.1 kg. Eight skinfold measurements were taken with a Harpenden caliper (Baty International, RH15 9LB, England; width of 80 mm and accuracy to 0.2 mm) from the following defined ISAK sites: triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, frontal thigh, and medial calf. Percentage of body fat was estimated according to Yuhasz's equation (219) and muscle mass (kg) to Matiegka's equation (220).

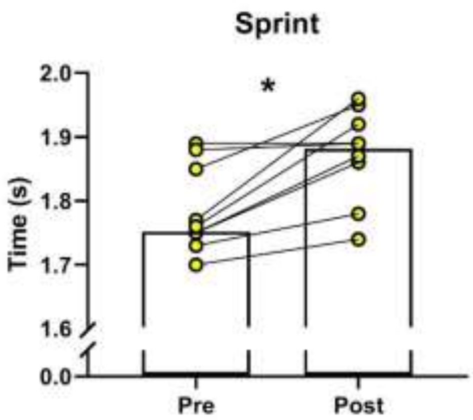
12.2.4. Statistical Analysis

Data are presented as mean ± SD. Statistical analysis was performed using the Jamovi statistical package (2020; version 1.2). Normality was checked with the Shapiro-Wilk test. A paired sample t-test (parametric variables) or a Wilcoxon test (nonparametric variables) was used to detect differences between pre-post measurements. Cohen's effect sizes (ESs) with 95% confidence intervals (95% CIs) were computed to determine the magnitude of every paired comparison and classified as follows: trivial (,0.2), small (.0.2–0.6), moderate (.0.6–1.2), large (.1.2–2.0), and very large (.2.0–4.0) (173). Significance level was set at $p \leq 0.05$.

12.3. RESULTS

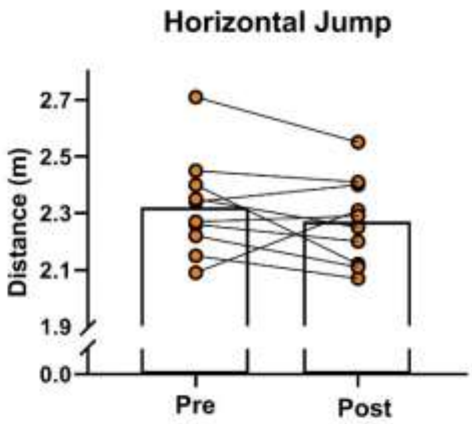
Figures 13 and 14 display the group and individual data for sprint and horizontal jump performances, respectively. Considering sprint, a significant and large decrease in performance was observed ($p = 0.004$; ES = 1.31). By contrast, small and nonsignificant pre-post differences were found in horizontal jump ($p = 0.243$; ES = 20.39).

Figure 13 Pre-quarantine and post-quarantine sprint time data.



Bars represent mean values, and symbols and lines represent individual changes. *p ≤ 0.05.

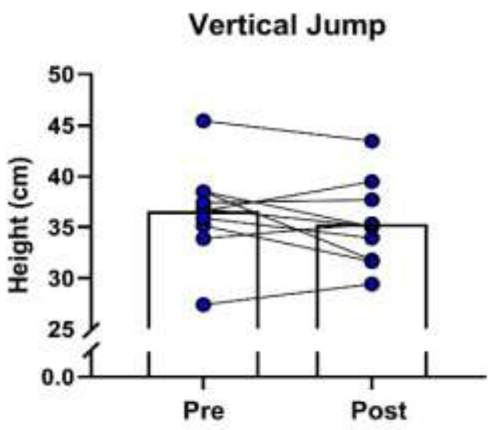
Figure 14 Pre-quarantine and post-quarantine horizontal jump distance data.



Bars represent mean values, and symbols and lines represent individual changes.

Figure 15 presents the group and individual data for vertical jump performance, and Table 14 depicts the data for selected CMJ kinetic variables. Moderate and nonsignificant pre-post differences were found in vertical jump height (p = 0.076; ES = 20.63). In the CMJ ECC ("downward") phase, significant decreases were observed in DEC impulse (p = 0.006; ES = 21.13), RFD (p = 0.041; ES = 20.75), peak velocity (p = 0.006; ES = 1.12) and peak power (p = 0.004; ES = 1.23). Nonsignificant, trivial or small declines were detected in all CON ("upward") phase variables and landing RFD to peak force (p = 0.129; ES = 20.52). Moderate significant differences were found in peak force (p = 0.050; ES = 20.70) during the landing phase.

Figure 15 Pre-quarantine and post-quarantine vertical jump height data.



Bars represent mean values, and symbols and lines represent individual changes.

Table 14 Comparison of countermovement jump kinetic variables before and after the confinement.

Variables	Units	Pre	Post	*p* value	Effect Size (95% CI)
		Mean ± SD	Mean ± SD		
Jump Height	cm	35.78 ± 4.58	34.10 ± 3.54	0.076	-0.63 (-1.30 – 0.06)
DOWNWARD ("ECCENTRIC") PHASE					
Decel Impulse	Ns/kg	1.36 ± 0.14	1.19 ± 0.16	0.006*	-1.13 (-1.91 – -0.30)
Peak Velocity	m/s	-1.39 ± 0.14	-1.21 ± 0.17	0.006*	1.12 (0.30 – 1.90)
Peak Power	W/kg	-20.85 ± 5.20	-16.40 ± 4.00	0.004*	1.23 (0.38 – 2.05)
RFD[a]	N/s/kg	77.39 ± 23.46	67.82 ± 24.68	0.041*	-0.75 (-1.44 – -0.02)
UPWARD ("CONCENTRIC") PHASE					
Impulse	Ns/kg	2.67 ± 0.17	2.61 ± 0.13	0.091	-0.59 (-1.26 – 0.09)
Peak Velocity	m/s	2.78 ± 0.15	2.73 ± 0.13	0.096	-0.58 (-1.24 – 0.10)
Peak Power	W/kg	53.27 ± 6.09	53.48 ± 6.67	0.911	0.03 (-0.58 – 0.65)
LANDING PHASE					
Peak Force	N/kg	97.06 ± 24.92	76.88 ± 18.47	0.050*	-0.70 (-1.38 – 0.00)
RFD to Peak Force[b]	N/s/kg	3176 ± 2965	1948 ± 1320	0.129	-0.52 (-1.18 – 0.14)

*p < 0.05; significant pre –post differences analyzed by a Paired Sample T-Test.

CI: confidence interval; Decel: deceleration; RFD: rate of force development; SD: standard deviation.
aEccentric RFD: average RFD (Δforce/Δtime) calculated from the start of the eccentric yielding phase (minimum force [time 1]) to the end of downward ("eccentric") phase [time 2];
bRFD to Peak Force: average RFD calculated from landing [time 1] to landing peak force [time 2]. Impulse, Force, RFD and Power variables are expressed relative bodyweight.
Note: As downward ("eccentric") phase velocity and power are negative values, the decrease in values for these variables manifests as a positive ES.10

Table 15 depicts the data for the body composition variables pre-post confinement. Trivial and nonsignificant differences were obtained in total body mass (p = 0.992; ES = 0.00), fat mass (p = 0.947; ES = 20.02), and muscle mass (p = 0.734; ES = 20.11).

Table 15 Comparison of body composition variables before and after the confinement.

Variables	Pre Mean ± SD	Post Mean ± SD	Mean Diff (%)	*p* value	Effect Size (95% CI)
Body composition					
Body Mass (kg)	76.0 ± 6.6	76.0 ± 6.7	0.1 ± 4.2	0.992	0.00 (-0.61; 0.62)
Fat Mass (%)	9.29 ± 1.46	9.28 ± 1.70	-0.3 ± 6.0	0.947	-0.02 (-0.64; 0.59)
Muscle Mass (kg)	50.1 ± 1.56	50.0 ± 1.48	-0.1 ± 1.5	0.734	-0.11 (-0.73; 0.51)

*p <0.05; significant pre –post differences analyzed by a Paired Sample T-Test.
CI: confidence interval; SD: standard deviation.

12.4. DISCUSSION

To the best of our knowledge, this is the first study to investigate the effects of 70 days of reduced training caused by the COVID-19 on speed-power–related performance and body composition in elite futsal players. Notably, the main findings indicated that (a) a significant impairment in short sprint (i.e., acceleration) performance was found after the quarantine period; (b) vertical jump height was not significantly affected during home confinement but significant differences were observed in specific ECC "downward" and landing phase kinetic variables; (c) horizontal jump performance was not significantly affected during lockdown; and (d) players experienced no significant changes in body composition. The present data indicate that long-term reduced training may have a negative effect on ACC capabilities and alter aspects of neuromuscular performance identified by vertical jump kinetic analysis. Yet, vertical jumping height and horizontal distance can be maintained for prolonged periods (70 days) in PRO futsal players by completing training routines based on exercises that can be performed at home, without thorough supervision or the need for additional training equipment.

Considering sprinting-acceleration performance, it seems that long-term reduced training (8 weeks) may affect sprint capabilities of elite futsal athletes. Importantly, in this unusual scenario (i.e., 70 days of home confinement), players were unable to perform any type of high-intensity running actions due to the mandatory lockdown (i.e., spatial constrains), which may have contributed to the observed declines in ACC ability. These results support previous findings showing impairments in sprint performance after long-term reduced training in soccer players (209, 214, 221). For example, Koundourakis et al. (209) observed that after a 6-week training cessation (i.e., 2 weeks abstained from any activity and 4 weeks performing only 20–30 minute slow running 3 times per week), the sprint velocity of elite soccer players decreased significantly. Potential factors explaining these adaptations include an insufficient sprinting stimulus (training volume and intensity), changes in muscle fiber type and in cross-sectional area of type II fibers, or alterations of anaerobic enzymatic activity (222, 223). From an applied perspective, coaches should be aware that impairments in ACC ability may be expected after long-term training cessation or reduced training in team-sport players. Thus, for these athletes, returning to training practices after prolonged periods of low volume of high-intensity running and sprint training should focus on progressively developing the speed-related qualities, from the early ACC to maximum velocity phases.

Of note, horizontal and vertical jumping distance and height, respectively, were not influenced by the quarantine, which is in line with previous studies investigating long-term training cessation (i.e., 4 weeks) in team-sports (66, 224). In a sample of high-level handball players, Marques et al. (224) reported that a period of 7 weeks of reduced training did not negatively affect CMJ_{height}. By contrast, an investigation into elite soccer players revealed significant decreases in CMJ and squat jump after a transition period of 6 weeks (209). These results might be explained by possible changes in fiber type morphology (222) due to the complete absence of plyometric training during the period (note that in the study by Koundorakis et al. (209) players performed only slow-running activities for 20–30 minute, 2 to 3 times per week). Regarding our study, it is important to highlight that (a) futsal players performed a semi-structured maintenance training program comprising vertical and horizontal jumps throughout the lockdown in an attempt to minimize potential declines in neuromuscular performance (79) and (b) individual responses differed among players (as seen in Figures 14 and 15), which suggests that tailored training strategies may be necessary. Nevertheless, in applied terms, jumping ability (i.e., as determined by jump height) seems to be maintained during prolonged periods of reduced training. Therefore, coaches are encouraged to prescribe different types of vertical and horizontal jump exercises during long-term reduced training periods, keeping in mind that individual responses may vary among players.

An interesting and novel finding in this study was that a thorough analysis of CMJ kinetics revealed that ECC (i.e., DEC impulse, peak velocity and power, and RFD) and landing variables (i.e., peak force) were significantly affected by the reduced training period, in line with a recent study conducted with PRO soccer players (66). Specifically, Cohen et al. (66) found that a long-term reduced training (i.e., players completed an isolated resistance and aerobic interval training) during the quarantine was successful in maintaining jump height, peak CON power, and several other kinetic variables, but not specific ECC and landing force, RFD, and velocity metrics. This suggests potential alterations on stretch-shortening cycle mechanisms, muscle-tendon properties (66), or movement strategies used by the athletes that may impair, for instance, their ability to rapidly and efficiently decelerate (i.e., high ECC loading). Noteworthy, another investigation (214) demonstrated a significant decrease in CMJ (i.e., an ECC-CON action) but not in squat jump (i.e., CON-only movement) height after the quarantine in soccer players, which further supports that ECC and landing qualities are more sensitive and harder to retain during extended periods of reduced training. Still, further studies are necessary to identify the precise mechanisms explaining this phenomenon and to allow providing more robust recommendations for returning to competition practices, after extended absences off-court.

Regarding body composition, it is well established that a reduction in physical activity levels diminishes energy expenditure (216). Therefore, decreasing energy intake may be necessary to avoid undesirable changes in body composition (e.g., increases in body fat). Remarkably, the mandatory confinement seemed not to affect players' body composition (i.e., total body mass, body fat percentage, and muscular mass). The results of this research are not supported by other studies investigating the effects of prolonged training cessation (209, 214, 225). In this context, Ormsbee et al. (225) noted that swimmers' body composition and metabolism were adversely affected after more than a month of training cessation that usually occurs after the last competition of the season. Our results may be explained by the fact that futsal players had continuous contact with the team's nutritionist, who prepared individualized dietary plans every 2 weeks according to player's needs, and the caloric intake was reduced during the lockdown when compared with the In_{se}. Furthermore, players were highly motivated to follow the nutritional guidelines imposed because shortly after the confinement they had to play the Spanish League Playoffs; thus, they were expected to be prepared to return to a decisive phase of the competition within few weeks after the lockdown. This contrasts with other studies (209, 225) in which detraining comprised unstructured light -moderate physical exercise (mainly running-based activities, e.g., 20–30 minute jogging, 2–3 times per week), was part of the transition phase, and was followed by a specific Pre_{se} period with limited competition demands.

12.5. LIMITATIONS

This study is limited by its small sample size. Nevertheless, it is important to note that the futsal team (a UEFA Futsal Champions League finalist) was composed of only 12 athletes, from which 10 were tested pre-lockdown and post-lockdown, representing more than 83% of the team's players. A second limitation is related to the difficulty of the S&Cc to (remotely) control the training sessions during the lockdown that may have affected individual responses. Finally, more tests investigating players' neuromuscular performance (i.e., COD ability, unilateral/bilateral drop jumps, and maximal ECC/CON strength) could allow to better describe the effects of the COVID-19 home confinement on physical performance.

12.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In summary, a detrimental effect of the lockdown was found for sprint performance and specific CMJ kinetic ECC and landing phase variables in elite futsal athletes. Nevertheless, vertical jump height, horizontal jumping distance, and body composition were not affected. The inclusion of "regular" unloaded lower-body exercises performed at home, without thorough supervision may conceivably explain why athletes were able to maintain their CON jump performance (but not ACC ability and underlying neuromuscular qualities identified in the ECC and landing phases of the CMJ) after the 70 days of reduced training. Coaches and sport scientists should consider the present findings when planning the specific training approaches after long-term reduced training periods.

Long-term reduced training caused by home confinement had a large negative effect on the ACC performance of elite futsal players, most probably due to the lack of an appropriate sprint training stimulus. By contrast, as players were able to perform jump-type exercises at home, horizontal jump distance and vertical jump height were not significantly impaired (although moderate ESs were found for the latter). Nevertheless, it is important to highlight that different variables, specifically in the ECC and landing phases, were found to be significantly affected by the prolonged reduced training period. This finding highlights that implementing a thorough analysis of players' CMJ jump-land kinetics may reveal detraining-related neuromuscular strategy changes that are not expressed in vertical jump height declines, an approach previously shown to be of value in detecting neuromuscular fatigue (39, 40). In addition, no changes were found in body composition, emphasizing the importance of having players follow individual dietary plans during prolonged periods of decreased TL. From an applied perspective, sprinting ACC and DEC (i.e., ECC biased) training strategies should be prioritized when returning to regular training practices to counteract the negative effects caused by long-term reduced training. Moreover, considering players' individual responses, it seems that a low (but frequent) volume of jumping-based exercises (2–3 sets of 6–8 repetitions of vertical and horizontal, unilateral and bilateral jumps, 2 sessions per week) may be sufficient to avoid impairments in jumping capacity (i.e., as determined by jump height) during long-term reduced training periods (i.e., 70 days) in elite male futsal players. However, practitioners should take into account that, as suggested by the significant CMJ kinetic changes, important alterations may still have occurred, which could potentially influence other performance-related and injury-related aspects (e.g., DEC ability or muscle-tendon properties).

XIII – STUDY 9

XIII. STUDY 9

INJURY RATES FOLLOWING THE COVID-19 LOCKDOWN: A CASE STUDY FROM AN UEFA FUTSAL CHAMPIONS LEAGUE FINALIST

13.1. INTRODUCTION

In 2020, a pandemic disease (i.e., COVID-19) arose complicated circumstances for athletes, clubs, and sports competitions (226). Most European countries postponed or canceled their respective championships as players were forced into a long-term lockdown during the in-season period (March-May). This unprecedented situation led National leagues and federations to adjust the competitive calendars to allow finishing the competitions in due time. For example, the LNFS (1st Division of Spain) determined that the league's first play-off game was to be played within few weeks after a ~60-day lockdown, a period with reduced training. Therefore, several recommendations were provided by the scientific community to tackle the potential detraining effects on physical performance and minimize the risk of injury when returning-to-competition after the lockdown (79, 227, 228).

Futsal is a high-intensity intermittent team-sport, in which players are exposed to high metabolic and neuromechanical stress during match-play (61). Regarding injury characteristics, a recent meta-analysis (229) found that male players displayed: 1) an overall injury incidence rate of 6.8 injuries/ 1000-h and; 2) an incidence rate of 44.9 injuries/1000-h during match-play. Likewise, it was found that PRO players from the 1st and 2nd LNFS sustained ~10 injuries/ 1000-h of training and ~60 injuries/1000-h of competition during the Pre_{se} and that most injuries affected the lower-limbs (i.e., 92.1%) (181). Nevertheless, all previously published data are based on the analysis of "regular" competitive scenarios (i.e., no In_{se} breaks due to a lockdown) and no investigation has reported the effects of the unique situation caused by COVID-19 on injury occurrence in elite futsal.

Therefore, the aims of this case study were to examine and compare the absolute and relative lower-limb injury rates 6 weeks pre- and post-lockdown. Due to the extensive period of reduced training, we hypothesized that the relative number of non-contact injuries would be greater after the season intermission (i.e., post-lockdown).

13.2. METHODS

13.2.1. Study Design

A pre-post retrospective cohort case study design was used. Due to the Covid-19 pandemic, all futsal activities (i.e., training and competition) were canceled on March 14th, 2020. The pre-lockdown injury profile was compiled from January 27th, 2020 to March 13th, 2020. During this period, players completed 53.3 ± 5.4 h of training and 6 matches. The post-lockdown injuries were collected from May 12th, 2020 to June 24th, 2020 (last league play-off game). Players completed 52.9 ± 2.8 h of training and 5 matches. These time periods were selected for further analysis to guarantee similar exposure time. Only non-contact lower-body injuries were analyzed (injuries caused by external factors, such as contact with other players, were disregarded). In the present study, an injury was defined as any physical complaint sustained by a player that resulted from a match or training, irrespective of need for medical attention or time loss from activities (204). The team's physician was responsible for the evaluation and recording of injuries according to the consensus statement of injuries in soccer (204), previously used in futsal (181).

13.2.2. Participants

Thirteen elite male futsal players (age: 27 ± 2.8 years; body mass: 76 ± 5.4 kg; height: 1.79 ± 0.1 m; body fat: 9 ± 1.6%), competing in LNFS and Finalists of the UEFA Futsal Champions League were monitored. By signing a PRO contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

13.2.3. Procedures

Injuries were classified according to: 1) severity; 2) location; 3) type; and 4) mechanism. No injury reoccurrence was observed; hence, this condition was excluded. Injury severity considered the time period from the day of the injury to the date of the player's return to full participation with the team and was classified as: minimal (≤3 days); mild (4 – 7 days); moderate (8 – 28 days); and severe (> 28 days). If the player sustained an injury but was available the following day, the incident was recorded as a time loss of zero-day severity. Injury location and type were classified and divided into six (i.e., hip-groin, thigh, knee, lower leg-Achilles tendon, ankle, foot-toe) and four categories (i.e., fractures and bone stress, joint [non-bone] and ligament, muscle and tendon, contusions), respectively (204). Injury mechanisms were classified as overuse (i.e., unidentifiable event, usually due to repeated micro-traumas) or traumatic (i.e., specific identifiable occurrence) (204).

Time exposure for each player considered the total time spent in training and competition. Team talks and video tactical sessions, meetings with sport psychologists and nutritionists, and personal activities undertaken away from the team's staff were not included. Injury rates were expressed per 1,000 hours of training and match combined.

13.2.4. Statistical Analysis

Statistical analysis was performed using SPSS Statistics, version 22.0 (SPSS, Inc., Chicago, IL). Descriptive data of absolute and relative number of injured athletes pre- and post-lockdown were reported. The distribution in the number of injuries between both periods of analysis was compared through the Chi-Square test and the z-test and the 95%.

13.3. RESULTS

Tables 16 and 17 report the pre- and post-lockdown lower-limb injury rates and characteristics. No lower-limb overuse injuries were observed pre-lockdown. Nevertheless, 38% (i.e., 5) of players suffered from non-contact overuse injuries after the lockdown in hip-groin and tight muscles, all sustained during training.

Chi-Square tests revealed a significant difference in the distribution of the number of injuries between the two moments (p = 0.039).

Table 16 Injury indices before and after the COVID-19 lockdown.

	Pre-Covid-19	**Post-Covid-19**	***p*** χ^2
Total Exposure Time (h)	53.3 ± 5.4	52.9 ± 2.8	
Total Injuries	-	5	
Injury Incidence ($n \cdot 1000\ h^{-1}$)	0	7.73 (95% CI: 2.19–13.27)	0.039

Values presented as mean ± SD.

$p \leq 0.05$; significant pre –post differences analyzed by a Chi-Square test.

h: hours; SD: standard deviation

Table 17 Injury characteristics post-COVID-19 lockdown.

Post-Covid-19 Injury Characteristics		
Mechanism of injury	Overuse	5
Injury severity	Minimal	5
Injury location lower-limbs	Hip/groin	4 (80%)
	Thigh	1 (20%)
Injury type	Muscle and tendon	5 (100%)

13.4. DISCUSSION

This case study identified a greater number of non-contact lower-body injuries (incidence of $7.73 \cdot 1000 \cdot h^{-1}$ [95% CI: 2.19 - 13.27]) after the lockdown in an elite futsal team. Specifically, ~40% of the players (i.e., 5) suffered minimal severity injuries (i.e., 3 days of court absence) during the 6 weeks following home-confinement. Conversely, no injuries were registered before the lockdown considering the same exposure time.

In general terms, overuse injuries are more common during the Pre_{se} when compared to the rest of season (230, 231). This has been suggested to occur due to inadequate REC and/or inappropriate loading during the first weeks of preparation following reduced training periods (i.e., transition period) (231). Considering the context of the present study, the post-lockdown period may be considered as a "mini preparatory phase" with the distinctive aspect that players returned from a home-confinement characterized by a sudden decrease in the number and frequency of high-intensity motor actions, especially those involving the stretch-shortening cycle (as compared to the in-season) (69). Moreover, players had only a few weeks to prepare for a highly demanding official play-off league match. Therefore, we speculate that some athletes were not able to cope with the high physical and technical demands of futsal training and competition; hence, the greater number of overuse injuries (232).

Previous studies have shown the detrimental effects of the COVID-19 lockdown on neuromuscular performance in elite team-sports athletes (66, 214). In particular, a recent study (69) using the same sample of elite male futsal players revealed that home-confinement resulted in a significant impairment in 10 m sprint performance. Of interest, vertical jump height remained unaltered, although several kinetic variables (i.e., ECC peak velocity and power, RFD, and landing peak force) were affected post-lockdown, despite players performing a maintenance training program while confined, as described elsewhere (69). Noteworthy, the main differences were obtained for the ECC and landing phases, suggesting that alterations on muscle-tendon properties (66) or stretch-shortening cycle mechanisms may have occurred during this period. To some extent, these important modifications can justify the higher number of injuries post-lockdown. These changes in neuromuscular function may have affected players' ability to efficiently decelerate and tolerate high ECC-loading actions, which is highly and frequently required in futsal (61).

It is important to highlight that futsal is characterized by high-intensity activities such as ACC, DEC, and directional changes (61). The issue here is that, during the lockdown, it was not possible to provide these types of stimuli to the players. In addition, the reduced period of training before competition could have resulted in the higher rates of injuries observed in the post-lockdown period, even considering that the number of matches was greater before the home-confinement (6 OFF matches vs 4 friendly and 1 OFF).

13.5. LIMITATIONS

Importantly, due to the reduced sample size and the elite level of the players examined here, the present results should not be generalized. Further retrospective investigations on pre- and post-lockdown injury rates with greater sample sizes and timeframes or involving athletes from different sports and performance levels are warranted.

13.6. CONCLUSIONS AND PRACTICAL APPLICATIONS

In summary, a significant increase in non-contact lower body injuries was observed after the COVID-19 lockdown in elite futsal players. Specifically, when considering an equal exposure time, the injury incidence was $7.73{\cdot}1000{\cdot}h^{-1}$ (95% CI: 2.19-13.27) after the quarantine, as opposed to no overuse injuries recorded pre-lockdown. Therefore, following long-term training cessation, practitioners are advised to: 1) implement a thorough analysis of players' neuromuscular qualities and fatigue [through vertical jump kinetics, for example (39)], to identify individual necessities and, thus, prescribe more tailored injury-reduction programs; 2) optimize REC strategies to allow players to better tolerate the high training and playing demands during congested calendars; and 3) closely monitor external and internal TL. Finally, sport organizations and federations should consider that players may need longer preparation periods to ensure safer return-to-competition practices after prolonged periods of training cessation or reduced training, and that competitive schedules should be adjusted to protect players' health and maintain optimal levels of performance throughout the competitive period.

XIV – SUMMARY AND DISCUSSION OF THE RESULTS

XIV. SUMMARY AND DISCUSSION OF THE RESULTS

The main objectives of the present compendium of studies was to analyze the match-play demands, player´s characteristics, and the fluctuation of the neuromuscular performance across season. The main results were that: 1) futsal players are exposed to high physiological, neuromuscular, and biochemical stress during, immediately after, and post 24 h following the game, with significant differences on match demands between halves, but not considering contextual factors; 2) OFF futsal matches presented higher intensity when compared to Non-OFF matches; 3) PRO futsal players cover greater distance, perform more high-intensity actions, and present lower standing time when compared to SEMI-PRO players; moreover, the former present low percentages of body fat, high physiological (i.e., VO_{2max}) and neuromuscular (i.e., sprinting, strength, and COD) capacities, and superior performance in the ECC metrics of the CMJ; 4) virtually all S&Cc report monitoring TL, most of them through the use of subjective tools, utilize the neuromuscular and strength measurements to evaluate performance and monitor fatigue, and practice ST and REC strategies for the physical preparation in futsal; 5) elite futsal players presented significant positive changes in CMJ jump landing phase following the Pre_{se}, however, CON peak power in CMJ decreased significantly during the competitive season, and lastly, neuromuscular performance (i.e., sprint, horizontal jump, and CMJ kinetic variables), body composition, and relative number of non-contact injuries were significantly negative affected by detraining period derived from COVID-19 lockdown.

Having all the above mentioned on mind, authors conducted the study 1 (61), which aimed to update and summarize the current state of literature on the match-play demands and physical, physiological, and neuromuscular characteristics of elite futsal players and to present the differences between competition levels. This systematic review provided useful information for S&Cc and sport scientists regarding the match demands, anthropometric characteristics, and physical qualities of elite and sub-elite male futsal players. The results indicate that futsal is characterized by intermittent high-intensity activities with a great number of ACC, DEC, and sprints, short REC times between them, and multiple COD actions during match-play. For example, Ribeiro et al. (24) analyzed a series of kinematic, mechanical and metabolic variables during match-play using GPS wearable devices and found that the total distance covered was 3749 ± 1123 m, sprinting distance corresponded to 135 ± 54 m, and players performed a great number of ACC_{HI} (87 ± 49) and DEC_{HI} (80 ± 32), when compared to the total number of jumps (9 ± 4). The abundance of these types of efforts produces important decrements in physiological and neuromuscular responses between the two halves and immediately following match-play. Due to high physical match demands, neuromuscular training (power- and speed-related development) should be one of the main objectives of S&Cc in futsal for the players´ physical preparation. Moreover, REC strategies should be used following the matches as biochemical responses (i.e., a decrease of plasma SlgA, increased muscle soreness, CK levels) appear to be affected up to 24 h after the match (9, 13, 15). Comparing competition level, differences were observed in match demands, with elite players covering higher distance, performing more high-intensity actions, and presenting lower standing time when compared to sub-elite players (6). An analysis of the anthropometric characteristics of futsal players showed low percentages of body fat with no differences between on-court players of different positions or level of competition, however, goalkeepers were found to present higher body fat (86, 87). Regarding the physiological characteristics of futsal players, these display VO_{2max} values of around 62 $ml \cdot kg^{-1} \cdot min^{-1}$. In this regard, PRO players have been reported to possess higher VO_{2max}, when compared to SEMI-PRO which could potentially explained by the greater match demands of the former with respect to the latter (49). Lastly, it appears that elite futsal players present better sprinting abilities when compared to lower-level players, but jump height seems not to differentiate between competition levels. Therefore, futsal players aiming to compete at the highest level should focus on developing maximal speed, lower-body power and strength, aerobic-anaerobic capacity, and lean muscle mass. In an applied setting, S&Cc should plan intermittent game-based drills that require multiple high-intensity efforts (e.g., short sprints in multiple directions or DEC) and speed-power exercises on training sessions.

Following the systematic review (61) that allowed summarizing the current state of the literature, the aim of study 2 (192) was to better understand the perspectives of futsal S&Cc working on the field. This was the first study to describe the TL monitoring and physical performance assessment practices and the characteristics of ST and REC strategies in PRO futsal. Of note, the vast majority (97.3%) of the S&Cc from Portugal and Spain reported monitoring TL (either internal or external) in PRO futsal. The most common method of recording TL was the RPE with 86.5%, followed by HR and GPS/accelerometry systems that were used by 40.5% and 37.8%, respectively. Considering player's physical capacities testing across the season, S&Cc generally evaluate body composition (81.1%), vertical jump ability (72.9%), muscular strength (70.3%), COD-agility (69.9%), followed by anaerobic capacity (54.1%) sprint (>10 m) (51.4%), aerobic capacity (43.2%), and ACC ability (<10 m) (40.6%). These tests are usually conducted monthly (29.7%), biannually (27.0%), trimonthly (21.6%), weekly (16.2%), and bimonthly (10.8%). Regarding player's fatigue, S&Cc reported conducting assessments mostly every week, with vertical jump height, muscular strength, and HR variability being the variables most commonly tested. Remarkably, it seems that neuromuscular and strength capacity evaluations are used to evaluate both performance and fatigue during the season with different frequency between practitioners in futsal. These results are in agreement with previous research (149, 153) that have demonstrated that jump tests, strength measurements, and sport-specific assessment protocols are commonly used in other team-sports, implemented on a weekly or monthly basis. When inquired about ST, all practitioners reported it to be a significant and highly important training component in futsal (i.e., 4.8 ± 0.4 out of 5). In the present study, S&Cc reported prescribing ST mainly 3 times/week (55.6%), with sessions lasting 31–45 min (32.4%), 16–30 min (29.7%), or 46–60 (24.3%) in the Pre$_{se}$. During In$_{se}$, practitioners declared performing 3 weekly ST sessions (45.9%), but with shorter durations (16–30 min, 45.9%; 31–45 min, 27.0%; and 46–60, 21.6%), most likely due to the limited time to dedicate to the development of physical qualities during the training week. Interestingly, these results are in line with the previous systematic review (61) that concluded the importance of developing sprinting, lower-body power and strength, aerobic-anaerobic capacity, and lean muscle mass in order to face up the high competitive demands. A novel aspect within this investigation was related to how S&Cc vary their ST practices depending on the competitive calendar (i.e., normal vs. congested weeks). Interestingly, the first ST during a normal week is performed mostly on the morning of MD + 2 (43.3%) and comprises both lower and upper body lifts (73%) and core (67.6%) exercises. During congested periods, short (i.e., 16–30 min, 45.9% or 0–15 min, 24.3%) ST sessions focused on the core musculature (62.2%) and (to a lesser extent when compared to normal weeks) lower and upper limb exercises (45.9%) are executed in the morning of MD + 2 (27.9%). However, these results should be interpreted cautiously as they are mainly anecdotal evidence, and more research is needed on the effects of ST on players′ performance and REC profile during normal and congested weeks in futsal. Considering the REC methods in futsal, it seems that S&Cc adjust REC approaches depending on the game location (i.e., 'home' versus 'away'). Precisely, active REC, water immersion, and massage therapy appear to be more utilized following 'home' games when compared to 'away' (76.6% vs 35.1%; 64.9% vs 21.6%; 48.6% vs 37.8%, respectively). However, foam roller, stretching, nutritional, and supplementation strategies are independent of the game location as the percentages of each do not differ greatly. Of note, REC sessions are mainly taking place after the game (43.2% and 54.1% following 'home' and 'away' games, respectively) or on the afternoon of MD + 1 ('home': 40.5%; 'away': 27%) and last 15–30 min. These results present great interest, as they indicate that S&Cc apply REC strategies immediately and 24 h after the game, which, as outlined in the systematic review (61), is a critical period where biochemical responses appear to be affected following match-play (9, 13, 15). Nevertheless, more research on the effects of different REC methods on futsal players and their individual response is warranted.

The previous two studies (61, 192) demonstrated that futsal players are exposed to high physical demands and that practically all the S&Cc monitor the game and TL in futsal. However, the influence of contextual factors in futsal match-play demands were not clarified. Having that in mind, the study 3 (133) aimed: 1) to quantify the match external load and movement demands during competitive PRO futsal matches while identifying differences between time periods (i.e., 1st and 2nd halves) using accelerometer-based technology; and 2) to investigate whether contextual factors (i.e., opposing team's ranking, match outcome, and location) affect external load variables during the match. Regarding match demands, the present results reinforce previously published research (1, 3-5, 27, 28) and confirm, through accelerometry data, that futsal is, indeed, a high-intensity intermittent modality in which players perform multiple ACC_{HI}, DEC_{HI}, and COD_{HI} actions (95). Of note, when analyzing game periods (i.e., halves), players displayed higher total

PL, PL·min^{-1}, and DEC_{HI} and EXPL-MOV in the 1st half when compared to the 2nd. Similar results were obtained by other authors (1, 4, 5, 7) using time-motion analysis and indicating that the percentage of distance covered at medium and high-velocity, and sprinting was greater during the 1st half. However, reports of no meaningful differences between the two halves can also be found in the literature (3, 28). For example, Ribeiro et al. (28) found that kinematic (i.e., distance covered per min, sprints), mechanical (i.e., ACC, DEC), and metabolic variables (i.e., metabolic power per min) were not affected by time-periods. Regarding the influence of the opposing team's ranking on the league, no meaningful differences were observed on any external load variable which indicates that similar physical demands are placed on players when playing against the top or bottom competitors, in order to achieve a positive result. Along the same lines, related studies (124, 128) on other team-sports have displayed similar physical match-demands against low-, medium- and, high-level opponents. However, Goodale et al. (127) found that total distance covered and activities at moderate and high-speeds were higher when playing against the top-4 opponents when compared to the bottom-4. Considering match result (i.e., Win-Loss), no significant differences were found on external match load. The present data do not seem to support a previous study (126) that found that the number of jumps, ACC_{HI}, DEC_{HI}, and COD were higher during losses when compared to wins in basketball. Additionally, Vescovi et al. (129) observed that relative sprint distance was greater during losses than draws in PRO women soccer players. Lastly, the external match load and activity profile were similar regardless of the game location (i.e., home versus away). Previous research (125, 129) from other team-sports supports the present results. PRO female soccer's players were found to experience no differences on physical demands irrespective of match location (129). Conversely, related studies (139, 140) have reported a significant decline on performance when playing "away" compared to "home". There are important factors that could influence the outcomes such as sport characteristics (i.e., futsal, soccer, and rugby), travel time or even time-zone changing since long-haul, and trans meridian travelling has been suggested to affect players' performance (141, 142).

Following study 3 (133), more information about the match external load and movement demands identifying differences between time periods (i.e., 1st and 2nd halves) and contextual factors (i.e., opposing team's ranking, match outcome, and location) was available. However, as mentioned above, the WCS may be considered more accurate to quantify the most intense periods of the game because the "average approach" may overlook variations and obscure the most intense periods of the play (35). Given that, the study 4 (233) aimed to compare and analyze the WCS in futsal considering: 1) OFF and Non-OFF matches; 2) calculated by two methods (i.e., ROLL and FIX); and 3) four different time-periods (i.e., 30 s, 1, 3, and 5 min). Match-play intensity during OFF competitions (e.g., LNFS and UEFA Futsal Champions League), as determined by PL·min^{-1} and calculated via ROLL, was found to be higher than during Non-OFF matches when considering the time-windows of 30 s and 1 min. This could be explained by the importance of the OFF games, in which "winning" is the main goal, and players are more likely to engage in maximal intensity efforts as opposed to friendly matches that are mainly focused on developing tactical, technical, and physical capacities (155). Notably, no difference in WCS was found between the matches as time-windows increased (e.g., 3 and 5 min intervals). It appears that larger time-epochs (i.e., >3 min) may obscure the most intense periods of the OFF competitions and overlook the "actual intensity" of these matches, possibly because futsal players barely spend >5 min on the court due to unlimited substitutions (130). In brief, WCS calculated over longer intervals seem to be closer to the match average intensity obtained with the "average approach". Regarding the different WCS computation methods, the FIX approach underestimated the intensity in futsal matches when compared to the ROLL in 30 s, 1, and 3 min intervals. These results are in line with previous research from different team-sports (145, 151, 152). For example, Cunningham et al. (152) found that the FIX method undervalued the maximum and high-speed running distance covered irrespective of the time-window (i.e., 60 – 300 s) in rugby players. Similar results were obtained in soccer players, with the FIX method underestimating the relative total and high-speed distances during match-play when compared to ROLL (154). Interestingly, no significant differences between the two methods were found within the 5 min time-window herein. Again, this finding supports that the utilization of large time-periods to determine the WCS is not recommended, as they do not accurately portrait the game's most demanding passages. The intensity significantly declines as time extends from 30 s to 5 min by both the FIX and ROLL approaches.

With regards to players' neuromuscular performance, the systematic review (61) reported no significant differences found between PRO and SEMI-PRO players on jumping ability when considering CMJ_{height}. However, to obtain more detailed information, a comprehensive kinetic analysis of CMJ might be warranted to detect differences between the competition levels. Subsequently, the main aims of study 5 were to compare the CMJ kinetic variables (i.e., CMJ_{height}, COM displacement, flight-contraction time, RSI_{mod}, and ECC and CON duration, peak force, power, and velocity) between PRO and SEMI-PRO futsal players; and compare the differences in the above-mentioned metrics among playing positions (i.e., D, W, and P). Regarding the differences in jumping ability between competition levels, previous studies (50, 57) found that PRO players presented equal CMJ_{height} values when compared to SEMI-PRO players. Similar results were obtained in the current study, when considering CMJ_{height}. However, a more comprehensive analysis of several kinetic variables during the jump-land cycle, displayed that PRO players had a better ECC capacity, performed a deeper COM displacement, generated greater absolute and relative peak power, and achieved greater peak velocities when compared to SEMI-PRO players. This difference could be explained by the higher number of matches and training sessions (and consequently, greater DEC actions) that PRO players expose to (i.e., ~50 vs ~30 games and ~6 vs ~3 training sessions per week) when compared to SEMI-PRO counterparts. Furthermore, it is important to highlight that PRO players cope with higher physical match-demands, and thus, this could make to present a better stretch-shortening cycle mechanism and muscle-tendon properties compared to lower-level players. Comparing the vertical jump ability amongst playing positions (i.e., D, W, and P) non-significant with trivial-small effect was found in any CMJ metric. These results are in line with a previous study (187), that compared the CMJ_{height} among goalkeeper, D, W, and P.

Once the differences in specific vertical jump metrics between competition levels were analyzed it was deemed interesting to understand how neuromuscular performance fluctuated across the different phases of the season. Firstly, study 6 aimed to investigate the fluctuations in neuromuscular performance (i.e., sprinting and jumping ability) across the initial 10 weeks of the season (including Pre_{se} and In_{se}) in a sample of elite futsal players. The main findings were that: 1) jump height did not change during the Pre_{se} and in the early competition season; 2) improvements in specific CMJ kinetic variables (i.e., RSI_{mod}, ECC peak force, ECC Dec RFD and CON peak force) were observed post Pre_{se} which indicated an enhanced neuromuscular status; 3) positive changes were also found in ECC Dec RFD and ECC duration when comparing In_{se} to Pre_{se}; and 4) a significant time interaction was found in sprint time (that improved post Pre_{se} and deteriorated in the early competitive season); however, changes between periods were small and non-significant. Regarding vertical jump performance, several CMJ metrics (i.e., RSI_{mod}, ECC peak force, ECC DEC RFD, ECC duration, and CON peak force) improved from Pre_{se} to early competitive season (In_{se}). Of note, jump height was not altered during the first 10 weeks of the season while specific CMJ metrics significantly changed post Pre_{se} and In_{se}. Similar results have been observed in other team-sports in the sense that meaningful alterations in jump height were not detected in response to loading or unloading, whereas a more thorough kinetic analysis of the CMJ revealed significant changes in neuromuscular function (40, 66-69, 198). While the overall time interaction for sprint performance was significant, non-significant changes were detected when comparing the different phases. Specifically, players were faster after the Pre_{se} but performance deteriorated during early In_{se}, which aligns with previous studies (77, 194, 199, 200).

Furthermore, when exploring the differences in neuromuscular performance amongst Pre_{se}, post Pre_{se}, and In_{se}, more questions were raised about the fluctuations during the season. Accordingly, study 7 (195) was designed and aimed to examine potential changes in speed-power related outputs (i.e., sprint speed, SLJ distance and vertical jump height) and CMJ kinetic variables (derived from the ECC, CON, and landing phases) across the season in elite futsal players. It appears that elite futsal players were not able to improve their sprinting ability throughout the competitive period (they sustained a gradual non-significant decline), aligning with previous findings in team-sports athletes (77, 194, 199). This phenomenon could be related to the concurrent training effect between power and endurance adaptations across the season, as well as the insufficient REC during congested periods (194, 205). From an applied standpoint, it is important to note that in the present study, despite not achieving statistical significance, sprint times were ~5% (ES = 1.05) higher (i.e., indicating lower performance) in Jan when compared to Sep, suggestive of a gradual decrease in maximal sprinting ability across the season. Periodic assessment of this quality during the competitive period could identify potential neuromuscular performance impairments, allowing individualized power-speed oriented training prescription according to a player's competition and training cumulative load and response thereof. Moderate but non-significant decrements in jumping ability were observed throughout the season. Mean CMJ_{height}, and SLJ distance values were, on average, 5.1% (ES = -0.48) and 3.9% (ES = -0.54) lower, respectively, in Jan when compared to Sep aligning with findings in other studies in team-sports (68, 70, 72, 74). For example, Kipp et al. (68) observed that while team-average jump height did not change over the course of the season, in individual players, greater competition volume was associated with decreased CMJ_{height} in female collegiate volleyball players. In PRO ice-hockey, a significant decrease in CMJ_{height} across the season was found (67). In contrast, an investigation in NBA players revealed that, in players with greater playing minutes, repetitive vertical jump power and lower body-power increased during the competitive period (203). These divergent results could be explained by the characteristics or loading demands of the sports investigated (e.g., basketball vs ice-hockey) and timing of the re-test (i.e., Pre_{se}, early season, mid-season, and late season, 36 hours after the last game vs before the start of the regular season and at the end of the regular season). In the present study, jump height had slight, steady but non-significant decreases over the season. A comprehensive kinetic analysis of the CMJ identified a significant and large (ES = 1.24) decline in CON peak power and small-moderate but non-significant effects in ECC and landing phase-specific metrics (i.e., peak power and velocity, RFD, duration, etc.), with the largest differences observed between Sep and Jan (Table 12). Significant changes in CMJ kinetic variables have been noted in studies in other team-sports athletes (67, 68). In PRO ice-hockey athletes, Gannon et al. (67) found that CON peak velocity and COM displacement decreased in the late-season when compared to the early-season. Moreover, the CON power decrements may reflect potential residual fatigue or the muscular-skeletal system that negatively affect power production capabilities as the season progresses (66). Therefore, sports practitioners, coaches, and scientist should be aware that a thorough kinetic analysis of the CMJ might provide valuable information regarding the neuromuscular status of the athletes that may not be obtained when analyzing jump height alone (40, 69). Lastly, frequent evaluations during the competitive period may allow to describe better the effects of training or competition stress on jump-landing cycle fluctuations. We also noted that while

CMJ_{height} steadily decreased, ECC (i.e., peak power and velocity, duration and COM displacement) and landing (i.e., peak force and RFD to peak force) metrics showed positive trends during specific time-points of the season.

Of note, it can be noticed that the previous study (195) during the season was conducted until Jan because on March of 2020 a novel virus COVID-19 was spread around the world, with almost all countries imposing a mandatory confinement. Among other occupations, the pandemic affected PRO sports, and athletes were forced to stay at home and not allowed to use the team's training facilities. As a consequence, the study 8 (69) aimed to investigate the effects of a 70-day reduced training period forced by the COVID-19 quarantine on speed-power–related capacities (i.e., sprint acceleration, horizontal jump, and vertical jump landing phases) and body composition (i.e., body mass, body fat percentage, and muscle mass) of elite futsal players. Considering sprinting-acceleration performance, it seems that long-term reduced training (8 weeks) may affect sprint capabilities of elite futsal athletes. Importantly, in this unusual scenario (i.e., 70 days of home confinement), players were unable to perform any type of high-intensity running actions due to the mandatory lockdown (i.e., spatial constrains), which may have contributed to the observed declines in ACC ability. These results support previous findings showing impairments in sprint performance after long-term reduced training in soccer players (188, 193, 200). Of note, horizontal and vertical jumping distance and height, respectively, were not influenced by the quarantine, which is in line with previous studies investigating long-term training cessation (i.e., 4 weeks) in team-sports (167, 203). In a sample of high-level handball players, Marques et al. (203) reported that a period of 7 weeks of reduced training did not negatively affect CMJ_{height}. By contrast, an investigation into elite soccer players revealed significant decreases in CMJ and squat jump after a transition period of 6 weeks (188). An interesting and novel finding in this study was that a thorough analysis of CMJ kinetics revealed that ECC (i.e., DEC impulse, peak velocity and power, and RFD) and landing variables (i.e., peak force) were significantly affected by the reduced training period, in line with a recent study conducted with PRO soccer players (167). Specifically, Cohen et al. (167) found that a long-term reduced training (i.e., players completed an isolated resistance and aerobic interval training) during the quarantine was successful in maintaining jump height, peak CON power, and several other kinetic variables, but not specific

ECC and landing force, RFD, and velocity metrics. This suggests potential alterations on stretch-shortening cycle mechanisms, muscle-tendon properties (167), or movement strategies used by the athletes that may impair, for instance, their ability to rapidly and efficiently decelerate (i.e., high ECC loading). Noteworthy, another investigation (193) demonstrated a significant decrease in CMJ (i.e., an ECC-CON action) but not in squat jump (i.e., CON-only movement) height after the quarantine in soccer players, which further supports that ECC and landing qualities are more sensitive and harder to retain during extended periods of reduced training. Lastly, body composition was not affected by home confinement.

This unprecedented situation produced by the COVID-19 led National leagues and federations to adjust the competitive calendars to allow finishing the competitions in due time. After exploring the detrimental effects produced by the 70-day detraining period that was reported in the previous study (195), it was noted that the effects of the home confinement on injury incidence were still unknown. Thus, study 9 (234) aimed to examine and compare the absolute and relative lower-limb injury rates 6 weeks pre- and post-lockdown. This case study identified a greater number of non-contact lower-body injuries (incidence of $7.73 \cdot 1000 \cdot h^{-1}$ [95% CI: 2.19 - 13.27]) after the lockdown in an elite futsal team. Specifically, ~40% of the players (i.e., 5) suffered minimal severity injuries (i.e., <3 days of court absence) during the 6 weeks following home-confinement. Conversely, no injuries were registered before the lockdown considering the same exposure time. In general terms, overuse injuries are more common during the Pre_{se} when compared to the rest of season (209, 210). This has been suggested to occur due to inadequate REC and/or inappropriate loading during the first weeks of preparation following reduced training periods (i.e., transition period) (210). Considering the context of the present study, the post-lockdown period may be considered as a "mini preparatory phase" with the distinctive aspect that players returned from a home-confinement characterized by a sudden decrease in the number and frequency of high-intensity motor actions, especially those involving the stretch-shortening cycle (as compared to the In_{se}) (171). Moreover, players had only a few weeks to prepare for a highly demanding official play-off league match. Therefore, we speculate that some athletes were not able to cope with the high physical and technical demands of futsal training and competition; hence, the greater number of overuse injuries (211). Previous studies have shown the detrimental effects of the COVID-19 lockdown on neuromuscular performance in elite team-sports athletes (167, 193). In particular, a recent study (171) using the same sample of elite male futsal players revealed that home-confinement resulted in a significant impairment in 10 m sprint performance. Of interest, vertical jump height remained unaltered, although several kinetic variables (i.e., ECC peak velocity and power, RFD, and landing peak force) were affected post-lockdown, despite players performing a maintenance training program while confined, as described elsewhere (171). Noteworthy, the main differences were obtained for the ECC and landing phases, suggesting that alterations on muscle-tendon properties (167) or stretch-shortening cycle mechanisms may have occurred during this period. To some extent, these important modifications can justify the higher number of injuries post-lockdown. These changes in neuromuscular function may have affected players' ability to efficiently decelerate and tolerate high ECC-loading actions, which is highly and frequently required in futsal (95).

In summary, futsal is an intermittent high-intensity sport with high physiological, neuromuscular, and biochemical stress during and following the match. PRO players have been found to cover greater distance, perform more high-intensity actions, and present lower standing time when compared to SEMI-PRO counterparts. Also, the former present low percentages of body fat, and high physiological (i.e., VO_{2max}) and neuromuscular (i.e., sprinting, strength, COD, and ECC metrics of the CMJ) capacities. The external match load significantly decreases on the 2nd half, but it is not affected by opposing team's ranking, match outcome, and location. When observing high peak periods, OFF presented significantly higher intensity in comparison with Non-OFF matches. Futsal S&Cc working in elite environments in Spain and Portugal regularly prescribe ST and employ REC strategies to optimize physical preparation in real world contexts. Moreover, almost all S&Cc apply neuromuscular and strength measurements to evaluate performance and monitor fatigue, and report monitoring TL, most of them through the use of subjective tools in order to detect the player´s physical fluctuations and adaptations during the season. When evaluating neuromuscular performance during different phases of the season, elite futsal players present significant positive changes in CMJ jump landing phase following the Pre_{se}; however, CON peak power in CMJ seems to decrease significantly during the competitive season.

Lastly, neuromuscular performance (i.e., sprint, horizontal jump, and CMJ kinetic variables), body composition, and relative number of non-contact injuries were significantly negative affected by the long detraining period derived from COVID-19 lockdown.

XV - CONCLUSIONS

XV. CONCLUSIONS

15.1. GENERAL CONCLUSIONS

The results of the present compendium of articles allowed concluding that futsal is a high-intensity intermittent sport, in which players are exposed to high physiological, neuromuscular, and biochemical stress during, immediately after, and post 24 h following the game. PRO futsal players cover higher distance, perform more high-intensity actions, and present lower standing time when compared to sub-elite players. Moreover, the former present low percentages of body fat, and high physiological (i.e., VO_{2max}) and neuromuscular (i.e., sprinting, strength, and COD) capacities. Regarding load monitoring, ST, and REC methods in futsal, virtually all S&Cc reported monitoring TL, most of them through the use of subjective tools. The neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and monitor fatigue. ST plays a crucial role in physical preparation in futsal with a typical ST session program consisting of 3 sessions per week during the Pre_{se} and In_{se}, and multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following "home" and "away" matches. Notably, futsal players were found to be exposed to high mechanical external loads and perform a great number of ACC_{HI}, DEC_{HI}, COD_{HI}, and EXPL-MOV during a match-play, with higher total PL, $PL \cdot min^{-1}$, DEC_{HI}, and EXPL-MOV obtained in the 1st half than the 2nd. Moreover, contextual factors (i.e. match result, team's ranking and match location) did not seem to affect any of the external variables. OFF matches presented higher WCS when compared to Non-OFF competition, quantified by ROLL. However, through this computation method, differences between match types were identified only when short time-intervals (i.e., 30 s and 1 min) were used. Considering the FIX approach, significant differences in WCS between the OFF and Non-OFF games were found in all time-windows. This method significantly underestimated the WCS from 30 s to 3 min, but not in the 5 min time-epoch compared to ROLL. Furthermore, irrespective of the computation method, 30 s intervals were found to display the highest WCS and 5 min, the lowest. PRO futsal players presented higher performance in the ECC metrics of the CMJ when compared to SEMI-PRO players, however, no differences on CMJ jump landing metrics were found amongst playing positions.

Considering the neuromuscular performance across the season, elite futsal players presented significant positive changes in RSI_{mod}, ECC peak force, Dec RFD, CON and ECC duration during the first 10 weeks of the season. Sprint time improved during Pre_{se} and deteriorated in the early competitive season; however, changes between these periods were small and non-significant. Other CMJ metrics, such as ECC peak power and velocity, COM displacement, CON peak power, velocity, and duration, and landing peak power showed small positive but non-significant changes across the two periods. During the competitive season, only CON peak power in CMJ decreased significantly. However, gradual and non-significant decrements were observed in multiple assessments (e.g., sprint time, SLJ distance, and vertical jump height). Other jump-landing phase cycle metrics (i.e., ECC peak power and velocity, duration, COM displacement, landing peak force and RFD to peak force) showed positive small-moderate fluctuations throughout the season. Lastly, neuromuscular performance (i.e., sprint, horizontal jump, and CMJ jump landing phase variables), body composition, and relative number of non-contact injuries were significantly negative affected by the lockdown period when to pre-COVID-19.

15.2. SPECIFIC CONCLUSIONS

The specific conclusions of the studies comprising the present thesis are displayed below. It is important highlight, that the conclusions of the following studies should not be generalized and used cautiously because of the high-level of the athletes and sport´s characteristics.

Study 1:

-Futsal players perform intermittent high-intensity activities with a great number of ACC, DEC, COD, and sprints, with short REC times between them during match-play.

-Elite futsal players cover higher distance, perform more high-intensity actions, and present lower standing time when compared to sub-elite players.

-Futsal match-play produce important decrements in physiological, neuromuscular, and biochemical responses between the two halves, post and post 24 h following match-play.

-Futsal players present low percentages of body fat, and high level of physiological (i.e., VO_{2max}) and neuromuscular (i.e., sprinting, strength, and COD) capacities.

Study 2:

-Virtually all coaches reported monitoring TL, most of them through the use of subjective tools, and neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and monitor fatigue.

-ST plays a crucial role in physical preparation in futsal and a typical ST session program consists of 3 sessions per week during the Pre_{se} and In_{se}.

-Multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following 'home' and 'away' matches.

Study 3:

-Higher external load (i.e., total PL, $PL \cdot min^{-1}$, DEC_{HI}, and EXPL-MOV) are obtained in the 1^{st} half than the 2^{nd}.

-Contextual factors (i.e. match result, team's ranking and match location) do not seem to affect any of the external variables studied.

Study 4:

-OFF matches presented higher WCS when compared to Non-OFF competition.

-WCS are higher when considering smaller (e.g., 30 s and 1 min) rather than larger time-epochs (e.g., 3 and 5 min).

-WCS is higher when calculated by ROLL in comparison to FIX method.

Study 5:

-PRO players presented a better ECC capacity, performing a deeper COM displacement, generating greater absolute and relative peak power, and achieving greater peak velocities when compared to SEMI-PRO players.

-No differences on CMJ metrics were found amongst playing positions.

Study 6:

-CMJ_{height} did not fluctuate in the early weeks of the season; however, positive alterations in phase-specific CMJ kinetics (i.e., RSI_{mod}, ECC peak force, Dec RFD, and duration) were found following Pre_{se} training in elite futsal players.

Study 7:

-From the several neuromuscular performance tests and variables assessed, only CON peak power in CMJ decreased significantly across the season.

Study 8:

-A detrimental effect of the lockdown was found in sprint performance and specific CMJ kinetic ECC and landing phase variables in elite futsal athletes. Nevertheless, vertical jump height, horizontal jumping distance, and body composition were not affected.

Study 9:

-The relative number of non-contact injuries were greater after the season intermission (i.e., post-lockdown).

XVI - LIMITATIONS

XVI. LIMITATIONS

Some limitations of the studies composing the present thesis must be addressed:

Study 1:

-The number of studies assessing each variable was quite different, which means that the evidence level was dissimilar among variables.

-The instruments, tests, or data collection procedures differed among studies.

Study 2:

-The results are based solely on the beliefs, experiences, or training philosophy of S&Cc. As such, the practices of different staff members (e.g., physiotherapists, nutritionists, etc.), who are directly involved in injury risk mitigation and REC strategies were not identified.

-Players did not participate in the survey, which limits access to important information such as whether they use further assistance on REC or physical preparation in their own time, outside club's facilities.

-Data were collected only from practitioners working in Spain and Portugal.

Study 3:

-The small sample size may have limited the extrapolation of the results.

-The match external load was monitored only for on-court players, and no goalkeepers' demands during the match-play were considered.

-The difference between the total number of matches classified as "wins" (n = 12) and "losses" (n = 5) may have influenced the analysis.

Study 4:

-This study is limited by its small sample size and only one team was recruited.

-Only four WCS time-windows (i.e., 30-s, 1-, 3-, and 5-min) and one external load variable (PL·min-1) were considered.

Study 5:

-Only one physical assessment (i.e., vertical jump test) was analyzed, which allows concluding about to the vertical jump ability of the players but not their overall neuromuscular capabilities.

-This study is limited by its small sample size to compare amongst playing position´s characteristics.

- CMJ data were collected only at the end of the Pre_{se} period (i.e., Sep), which did not allow us to conclude whether similar results would be obtained during the most crucial moments of the season.

-All the subjects competed in Spain and the results of this study should not be expand to other populations.

Study 6:

-This study is limited by its small sample size.

-Players' total training and match load were not recorded during the 10-week period.

Study 7:

-The season was abbreviated due to the COVID-19 pandemic.

-This study is limited by its small sample size.

-Participant´s total playing time, which could mediate the fluctuations of the neuromuscular performance throughout the season was not recorded.

Study 8:

-This study is limited by its small sample size.

-The difficulty of the S&Cc to (remotely) control the training sessions during the lockdown that may have affected individual responses.

Study 9:

-This study is limited by its small sample size and the duration of the data collection period post-lockdown.

XVII – PRACTICAL APPLICATIONS

XVII. PRACTICAL APPLICATIONS

From an applied and practical perspective, according to the results from the studies in the present thesis, futsal S&Cc and sport scientists should consider that:

-Intermittent game-based drills that require multiple high-intensity efforts (e.g., short sprints in multiple directions or DEC) and speed-power exercises should be prioritized in futsal training.

-Weekly training plan (from a physical preparation perspective) should not be altered whether the team plays at home or away, or against a top- or bottom-ranked opponent.

-Short time-periods (i.e., 30 s and 1 min) should be selected to quantify the WCS in futsal as these were the only ones found to be able to discriminate between different types of matches (i.e., OFF and Non-OFF).

-Larger time-periods (i.e., 3 and 5 min) appear to obscure the "actual intensity" to which the players are exposed to.

-ROLL seems to be more accurate than FIX to detect the WCS in elite futsal matches.

-Plyometric and ECC exercises performed during the training sessions may be interesting for muscle-tendon properties independently of the competition level.

-A more thorough analysis of the CMJ is recommended as neuromuscular changes that may occur, might not be expressed by CMJ_{height} alone.

-RSI_{mod}, ECC and CON peak force, ECC duration, and ECC Dec RFD appear to be more sensitive to neuromuscular adaptations of futsal players.

-A broad speed-power assessment during the season to evaluate players´ physical adaptations and adjust the training session accordingly.

-Sprinting, ACC and DEC (i.e., ECC biased) training strategies should be prioritized when returning to regular training practices to counteract the negative effects caused by long-term reduced training.

-Optimizing REC strategies and closely monitoring external and internal TL may allow players to better tolerate the high training and playing demands during congested calendars.

XIII - FUTURE RESEARCH LINES

XVIII. FUTURE RESEARCH LINES

After the completion of the present thesis, future research lines arise from the results obtained. In this regard, potential future investigations that could bring further understanding on the topics studied herein are presented below:

-To study the physical and physiological match play demands and players' characteristics in female futsal players.

-To study the effects on performance of current ST and REC methods reported by the S&Cc.

-To study the peripheral, central, and mental fatigue induced by futsal match-play.

-To study the match demands during normal game (i.e., 5 vs 5) when compared the demands with "fly-goalkeeper" on-court (e.g., 5 vs 4).

-To study the peak demands (i.e., WCS) considering the contextual factors (i.e., opposing team's ranking, match outcome, and location), technical-tactical parameters and between youth vs PRO, and male vs female matches.

-To study the differences on physical performance considering more assessments, such as sprint, COD, isometric mid-tight pull, and strength deficit in both PRO and SEMI-PRO players.

- To study the differences on physical performance (i.e., CMJ jump landing phase, sprint, COD, isometric mid-tight pull, and strength deficit) between male and female futsal players.

-To study the fluctuations on neuromuscular performance across the season with regards to the training and game time-exposure.

-To study the association between sprint performance and different CMJ jump landing phase metrics.

-To study the variations on neuromuscular performance across the season in female futsal players and the effects of menstrual cycle on performance.

XIX - MENCIÓN INTERNACIONAL

XIX. MENCIÓN INTERNATIONAL

Con el objetivo de cumplir con los criterios especificados en el Real Decreto 99/2011 para la obtención de la Mención Internacional en el Título de Doctor, se presentan las conclusiones del presente compendio de estudios en un idioma distinto al utilizado en la restante tesis.

19.1. CONCLUSIONES GENERALES

Los resultados del presente compendio de artículos permitieron concluir que el fútbol sala es un deporte intermitente de alta intensidad, en el que los jugadores están expuestos a un considerable estrés fisiológico, neuromuscular y bioquímico durante las 24 horas posteriores al partido. Los jugadores de fútbol sala profesionales cubren una mayor distancia, realizan más acciones de alta intensidad y presentan un menor tiempo de pie en comparación con los jugadores sub-élite. Además, los primeros presentan bajos porcentajes de grasa corporal y altas capacidades fisiológicas (VO_{2max}) y neuromusculares (sprint, fuerza, salto y COD). En lo que respecta a la monitorización de la carga, todos los S&Cc informaron de la monitorizan el TL, la mayoría de ellos mediante el uso de herramientas subjetivas. Las mediciones neuromusculares y de la fuerza se encuentran entre las estrategias que los profesionales utilizan para evaluar el rendimiento y controlar la fatiga. El entrenamiento de fuerza desempeña un papel crucial en la preparación física en el fútbol sala y un programa típico de sesiones consiste en 3 sesiones por semana durante la pretemporada y la temporada. Por último, se utilizan múltiples estrategias de REC (es decir, rodillo de espuma, estiramientos, estrategias nutricionales, y de suplementación) después de los partidos "en casa" y "fuera". Además, los jugadores de fútbol sala están expuestos a altas cargas externas mecánicas y realizan un gran número de ACC_{HI}, DEC_{HI}, CODHI y EXPL-MOV durante un partido, obteniéndose mayores PL totales, PL-min^{-1}, DEC_{HI} y EXPL-MOV en el primer tiempo que en el segundo. Los factores contextuales (es decir, el resultado del partido, la clasificación del equipo y el lugar del partido) no parecen afectar a ninguna de las variables externas estudiadas. Los partidos OFF presentan un mayor WCS en comparación con la competición Non-OFF, cuantificado por ROLL. Sin embargo, a través de este método de cálculo, sólo se identificaron diferencias entre tipos de partidos cuando se utilizaron intervalos de tiempo cortos (es decir, 30 s y 1 min). Considerando el enfoque FIX, se encontraron diferencias significativas en el WCS entre los partidos OFF y Non-OFF en todas las ventanas de tiempo. Además, este método subestimó significativamente el WCS de 30 s a 3 min, pero no en la franja de tiempo de 5 min en comparación con ROLL. Por último, independientemente del método de cálculo, se encontró que los intervalos de 30 s mostraban el mayor WCS y los de 5 min, el menor. Con respecto a las características y posiciones de los jugadores de fútbol sala, los jugadores PRO presentaron un mayor rendimiento en la métrica ECC del CMJ en comparación con los jugadores SEMI-PRO; sin embargo, no se encontraron diferencias en la métrica CMJ entre las posiciones de juego.

Teniendo en cuenta el rendimiento neuromuscular a lo largo de la temporada, los jugadores de fútbol sala de élite presentaron cambios positivos significativos en el RSI_{mod}, la fuerza ECC máxima, el Dec RFD, la CON y la duración ECC durante las primeras 10 semanas de la temporada. El tiempo de sprint mejoró durante la pretemporada y deterió en la temporada competitiva temprana. No obstante, los cambios entre los periodos fueron pequeños y no significativos. Otras métricas del CMJ, como la potencia máxima y la velocidad ECC, el desplazamiento del COM, la potencia máxima, la velocidad y la duración Con y la potencia máxima del aterrizaje mostraron pequeños cambios positivos, pero no significativos entre los dos periodos. Durante la temporada competitiva, sólo la potencia máxima de CON en CMJ disminuyó significativamente. Sin embargo, se observaron disminuciones graduales y no significativas en otras evaluaciones (por ejemplo, el tiempo de sprint, la distancia del SLJ y la altura del salto vertical). Otras métricas del ciclo de la fase de salto y aterrizaje (es decir, la potencia y la velocidad máximas ECC, la duración, el desplazamiento del COM, la fuerza máxima de aterrizaje y el RFD a la fuerza máxima) mostraron fluctuaciones positivas pequeñas y moderadas a lo largo de la temporada. Por último, el rendimiento neuromuscular (es decir, las variables de la fase de aterrizaje del sprint, el salto horizontal y el salto CMJ), la composición corporal y el número relativo de lesiones sin contacto se vieron significativamente afectados de forma negativa por el periodo de confinamiento en comparación con el periodo anterior a la COVID-19.

19.2. CONCLUSIONES ESPECÍFICAS

A continuación, se exponen las conclusiones específicas de los estudios que componen la presente tesis. Es importante destacar que las conclusiones de los siguientes estudios no deben generalizarse y deben utilizarse con precaución debido al alto nivel de los atletas y a las características del deporte.

Estudio 1:

-Los jugadores de fútbol sala realizan actividades intermitentes de alta intensidad con un gran número de ACC, DEC, COD y sprints, con cortos tiempos de recuperación entre ellos durante el juego.

-Los jugadores de fútbol sala de élite cubren una mayor distancia, realizan más acciones de alta intensidad y presentan un menor tiempo de permanencia en comparación con los jugadores de sub-élite.

-Los partidos de fútbol sala producen importantes disminuciones en las respuestas fisiológicas, neuromusculares y bioquímicas entre los dos tiempos, inmediatamente y después de las 24 horas posteriores al partido.

-Los jugadores de fútbol sala presentan bajos porcentajes de grasa corporal y un alto nivel de capacidades fisiológicas (es decir, VO2max) y neuromusculares (es decir, sprint, fuerza, salto y COD).

Estudio 2:

-Prácticamente todos los entrenadores informaron de la monitorización del TL, la mayoría de ellos mediante el uso de herramientas subjetivas, y las mediciones neuromusculares y de fuerza se encuentran entre las estrategias que los profesionales utilizan para evaluar el rendimiento y controlar la fatiga.

-La TS desempeña un papel crucial en la preparación física en el fútbol sala y un programa típico de sesiones de TS consiste en 3 sesiones por semana durante la pretemporada y la temporada.

-Después de los partidos "en casa" y "fuera" se utilizan múltiples estrategias de REC (es decir, rodillo de espuma, estiramientos, estrategias nutricionales y de suplementación).

Estudio 3:

-Se obtienen métricas de carga externa más altas (es decir, PL total, PL-min^{-1}, DEC_{HI} y EXPL-MOV) en el primer tiempo que en el segundo.

-Los factores contextuales (es decir, el resultado del partido, la clasificación del equipo y la ubicación del partido) no parecen afectar a ninguna de las variables externas estudiadas.

Estudio 4:

-Los partidos OFF presentaron un mayor WCS en comparación con la competición Non-OFF.

-El WCS es mayor cuando se consideran intervalos de tiempo más pequeños (por ejemplo, 30 s y 1 min) que más grandes (por ejemplo, 3 y 5 min).

-El WCS es mayor cuando se calcula con el método ROLL en comparación con el método FIX.

Estudio 5:

-Los jugadores PRO presentaron una mejor capacidad Ecc, realizando un desplazamiento COM más profundo, generando una mayor potencia máxima absoluta y relativa, y alcanzando mayores velocidades máximas en comparación con los jugadores SEMI-PRO.

-No se encontraron diferencias en las métricas del CMJ entre las posiciones de juego.

Estudio 6:

-La altura del CMJ no se modificó, sin embargo, se encontraron alteraciones positivas en la cinética específica de la fase del CMJ (es decir, RSI_{mod}, fuerza máxima ECC, Dec RFD y duración) tras el entrenamiento Prese. en jugadores de fútbol sala de élite.

Estudio 7:

-Pruebas de rendimiento neuromuscular y variables evaluadas, sólo la potencia pico concéntrica en el CMJ disminuyó significativamente a lo largo de la temporada.

Estudio 8:

-Se encontró un efecto perjudicial del bloqueo para el rendimiento del sprint y las variables específicas de la fase excéntrica y de aterrizaje del CMJ en los atletas de élite de fútbol sala. Sin embargo, la altura de salto vertical, la distancia de salto horizontal y la composición corporal no se vieron afectadas.

Estudio 9:

-El número relativo de lesiones sin contacto fue mayor después del intermedio de la temporada (es decir, después de cuarentena).

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XX. REFERENCES

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XXI – APPENDICES

APPENDIX 1. Study 1: PHYSICAL AND PHYSIOLOGICAL MATCH-PLAY DEMANDS AND PLAYER CHARACTERISTICS IN FUTSAL: A SYSTEMATIC REVIEW

Reference:

Spyrou, K., Freitas, T. T., Marín-Cascales, E., & Alcaraz, P. E. (2020). Physical and physiological match-play demands and player characteristics in futsal: a systematic review. Frontiers in psychology, 11, 569897.

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REVIEW
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Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review

Konstantinos Spyrou[1], *Tomás T. Freitas*[1,2,3*], *Elena Marín-Cascales*[1] and *Pedro E. Alcaraz*[1,3]

[1] UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain, [2] NAR – Nucleus of High Performance in Sport, São Paulo, Brazil, [3] Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain

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Cesar Mendez,
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***Correspondence:**
Tomás T. Freitas
tfreitas@ucam.edu

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Futsal, also known as five-a-side indoor soccer, is a team-sport that is becoming increasingly popular. In fact, the number of futsal-related investigations is growing in recent years. This review aimed to summarize the scientific literature addressing the match-play demands from the following four dimensions: time-motion/external load analysis and physiological, neuromuscular, and biochemical responses to competition. Additionally, it aimed to describe the anthropometric, physiological, and neuromuscular characteristics of elite and sub-elite male futsal players, contemplating the differences between competition levels. The literature indicates that elite futsal players cover greater total distance with higher intensities and perform a greater number of sprints during match-play when compared to sub-elite players. The physiological demands during competition are high (average intensity of ≥85% maximal heart rate and ~80% maximum oxygen uptake [VO_{2max}]), with decrements between the two halves. Research suggests that neuromuscular function decreased and hormonal responses increased up to 24 h after the match. Considering anthropometric characteristics, players present low percentage of body fat, which seems commonplace among athletes from different on-court positions and competition levels. Elite players display greater values and at VO_{2max} with respect to sub-elite competitors. Little is known regarding elite and sub-elite futsal players' neuromuscular abilities (strength, jumping, sprinting, and change of direction [COD]). However, it appears that elite players present better sprinting abilities compared to lower-level athletes. Futsal players aiming to compete at the highest level should focus on developing maximal speed, lower-body power and strength, aerobic capacity, and lean muscle mass.

Keywords: five-a-side soccer, game-analysis, performance, physical capacities, team-sports

INTRODUCTION

Futsal, also known as five-a-side indoor soccer, is a team-sport officially authorized by FIFA and is becoming increasingly popular all over the world. It is characterized as a high-intensity intermittent sport that imposes high physical, technical, tactical, and psychological demands on players (Barbero-Alvarez et al., 2008). The game is played five-a-side (i.e., four on-court players and one goalkeeper), in a 40 × 20 m court, with a 3 × 2 m goal post and an unlimited number of substitutions. The maximum number of players in a squad for a match is 14 (a maximum of 9 substitutes per team) (FIFA, 2020). A futsal match consists of two halves of 20 min separated by a 10 min break. Given that the game-clock is stopped for some events (i.e., ball out of the court, faults, corners), a competitive match may last between 75 and 90 min (Álvarez et al., 2002). During match-play, teams can request one timeout (1 min) in each half.

Of note, the number of futsal-related investigations is growing in recent years. Several studies have described competition demands (Dogramaci and Watsford, 2006; Barbero-Alvarez et al., 2008; Castagna et al., 2009; Dogramaci et al., 2011; Makaje et al., 2012; Bueno et al., 2014; Caetano et al., 2015; Milioni et al., 2016; Milanez et al., 2020; Ohmuro et al., 2020; Ribeiro et al., 2020; Yiannaki et al., 2020) by reporting the physiological (Barbero-Alvarez et al., 2008; Castagna et al., 2009; Rodrigues et al., 2011; Makaje et al., 2012; Charlot et al., 2016; Milioni et al., 2016; Bekris et al., 2020; Yiannaki et al., 2020), neuromuscular (Caetano et al., 2015; Milioni et al., 2016; Milanez et al., 2020; Ribeiro et al., 2020), or biochemical responses (Moreira et al., 2011; de Moura et al., 2013; Bekris et al., 2020) following a competitive match. In addition, different authors have shown particular interest in describing the characteristics of futsal players such as anthropometrics (Baroni and Leal Junior, 2010; Gomes et al., 2011; Jovanovic et al., 2011; Garrido-Chamorro et al., 2012; de Moura et al., 2013; Pedro et al., 2013; Ramos-Campo et al., 2014; Galy et al., 2015; Nikolaidis et al., 2019; López-Fernández et al., 2020) and physiological (Barbero-Alvarez et al., 2009; Gorostiaga et al., 2009; Baroni and Leal Junior, 2010; Castagna and Barbero-Alvarez, 2010; Milanez et al., 2011; Makaje et al., 2012; Boullosa et al., 2013; Oliveira et al., 2013; Pedro et al., 2013; Cuadrado-Peñafiel et al., 2014; Miloski et al., 2014; Soares-Caldeira et al., 2014; De Freitas et al., 2015, 2019; Galy et al., 2015; Garcia-Tabar et al., 2015; Charlot et al., 2016; Floriano et al., 2016; Nakamura et al., 2016, 2018; Naser and Ali, 2016; Barbieri et al., 2017; Barcelos et al., 2017; Valladares-Rodriguez et al., 2017; Nogueira et al., 2018; Zarebska et al., 2018, 2019; Farhani et al., 2019; Nikolaidis et al., 2019; Teixeira et al., 2019; Wlodarczyk et al., 2019, 2020; Bekris et al., 2020) and neuromuscular qualities (Gorostiaga et al., 2009; Gomes et al., 2011; Cuadrado-Peñafiel et al., 2014; Soares-Caldeira et al., 2014; Galy et al., 2015; Charlot et al., 2016; Miloski et al., 2016; Nakamura et al., 2016; Naser and Ali, 2016; Vieira et al., 2016; De Lira et al., 2017; Loturco et al., 2018, 2020; Nogueira et al., 2018; Nunes et al., 2018, 2020; De Freitas et al., 2019; Jiménez-Reyes et al., 2019; Nikolaidis et al., 2019; Sekulic et al., 2019; Teixeira et al., 2019). This is extremely important, since understanding the match position-specific demands and the physical requirements for elite futsal players is the foundation for planning an effective training program. With this is in mind, the objective of this review is to update and summarize the current state of literature on the match-play demands and physical, physiological, and neuromuscular characteristics of elite futsal players and to present the differences between competition levels. To the best of the authors' knowledge, this is the first systematic review to simultaneously characterize futsal match-play demands through different approaches (i.e., time-motion analysis and wearable technology external load data, and physiological, neuromuscular, and biochemical responses) and describe the players' physical attributes.

METHODS

Study Design

The present study is a systematic review focused on the match-play demands and players' characteristics (i.e., anthropometrics, physiological, and neuromuscular) at different levels of competition in futsal. The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2010) and did not require Institutional Review Board approval.

Search Strategy

A systematic search was carried out in PubMed, Web of Science, and SportDiscus, all high-quality databases that assure a strong bibliographic support. The search strategy considered all the related articles published until July 25th, 2020. To ensure that all studies related to this topic were identified, a broad and general search was conducted by using solely the following keywords in the search strategy: ("futsal" OR "indoor soccer" OR "five-a-side soccer"). All titles and abstracts from the search were cross-referenced to identify duplicates and any missing studies and then screened for a subsequent full-text review. The search was performed independently by two authors (KS, EM-C), and any disagreement was resolved by a third party (TF).

Inclusion and Exclusion Criteria

The review included cross-sectional and longitudinal studies published in English considering professional futsal players. The studies were included if they comprised (1) elite male futsal players; (2) sub-elite players, but only when compared to superior competition levels; (3) players $\geq$20 years old; and (4) variables related to the physical and physiological match-play demands and player characteristics (i.e., anthropometrics, physiological, or neuromuscular) were reported. Importantly, in the context of the current review, players were classified as elite if they competed in the National Team or 1st Division of their respective countries or in the 2nd Division of Spain, Portugal, Italy, or Russia. All the players that did not meet this standard were considered to be sub-elite.

Studies were excluded if (1) participants were $\leq$19 years old; (2) were female; (3) only sub-elite/state-level players participated in the study; (4) the division in which players competed was not detailed in the study (e.g., the players were referred to as "elite" but the article did not clearly mention that players competed in 1st Division); (5) non-English language; (6) the methodological quality assessment score was $\leq$8; and (7) the study consisted on a review or a conference paper.

Study Selection

The initial search was conducted by two researchers (KS, EM-C). After the removal of duplicates, an intensive review of all the titles and abstracts obtained was completed and the ones not related to the review's topic were discarded. Following the systematic screening process, the full version of the remaining articles was read. All studies not meeting the inclusion criteria were then excluded.

Data Extraction

Two reviewers (KS, EM-C) extracted the following data from the included studies: number and competitive level of the participants; match-play time-motion and physiological data; players' physiological and neuromuscular characteristics, the tests performed, measurement tools used, and outcome units. As the aim of the present review was not to investigate or determine the effects of different training programs on futsal players' physical qualities, in the studies in which interventions were used, the baseline values (i.e., pre-intervention) were extracted and reported in the respective tables in the Results section. In case the manuscript did not present numerical description of the data, the software GetData Graph Digitizer 2.26 (free software downloaded from http://getdata-graph-digitizer.com) was used to extract the outcome values from the articles' figures or graphs.

Methodological Quality Assessment

The methodological quality of the included studies was evaluated separately by two researchers (KS, EM-C) using the modified scale of Downs and Black (Downs and Black, 1998) (**Supplementary Material**). Disputes were resolved by a third party (TTF). Of the 27 criteria, 12 were applied according to the study's design, as observed in similar research previously published (Cummins et al., 2013; Whitehead et al., 2018).

RESULTS

Search Results

Figure 1 depicts the PRISMA flow diagram of the search and selection process of the studies. The initial databases yielded 2,346 citations, and 3 additional records were added through other sources. After duplicate removal, 1,536 articles

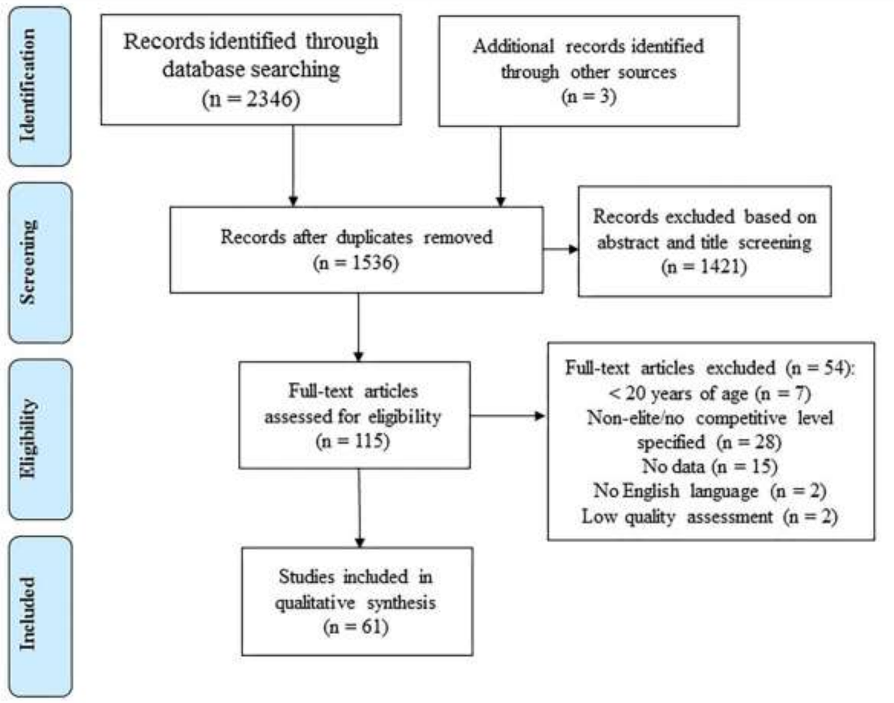

FIGURE 1 | Flow diagram.

remained. Upon title and abstract screening, 115 were left for the full-text review. Of the 115 articles reviewed, 61 met the criteria for the systematic review. Of the 61 the studies, 12 included time-motion analysis and match external load data, eight reported physiological responses to competition, four presented neuromuscular responses, and three considered biochemical responses. Regarding players' characteristics, 10 studies included anthropometric outcomes, 33 detailed physiological variables, and 21 investigated neuromuscular capabilities. Most of the studies were included in more than one section of the manuscript.

Match Demands

Time-Motion Analysis and External Match Load

Time-motion analysis and external load tracking is frequently used within team-sports to monitor and describe players' activity patterns and movements during competition (Mohr et al., 2005; Burgess et al., 2006; Ben Abdelkrim et al., 2007). In this context, total distance covered, average speed, the number and distance of sprints, accelerations (ACC), and decelerations (DEC) are the most commonly reported variables as they help describe match and players' positional demands (Bangsbo, 1994).

In futsal, several studies have used video analysis and computer-based tracking systems but only two studies have used wearable technology (GPS or accelerometer) to analyze match-play demands (**Table 1**) (Dogramaci and Watsford, 2006; Barbero-Alvarez et al., 2008; Castagna et al., 2009; Dogramaci et al., 2011; Makaje et al., 2012; Bueno et al., 2014; Caetano et al., 2015; Milioni et al., 2016; Milanez et al., 2020; Ohmuro et al., 2020; Ribeiro et al., 2020; Yiannaki et al., 2020). Most recently, Ribeiro et al. (2020) analyzed a series of kinematic, mechanical, and metabolic variables during match-play using GPS wearable devices (WIMU PRO™, Realtrack Systems, Almeria, Spain) and found that the total distance covered was 3,749 ± 1,123 m and sprinting ($\geq$18.0 km·h^{-1}) distance corresponded to 135 ± 54 m. Moreover, the authors reported that futsal players performed a great number of high-intensity ACC (87 ± 49) and DEC (80 ± 32), when compared to the total number of jumps (9 ± 4). Utilizing a different approach (i.e., time-motion analysis), Castagna et al. (2009) had previously investigated game activities and showed that high-intensity running ($\geq$15.5 km·h^{-1}) and sprinting ($\geq$18.3 km·h^{-1}) accounted for 12 and 5% of the whole match duration, respectively. Furthermore, players performed a sprint every 79 s with an average distance of 10.5 m, a duration of 1.95 s, and a recovery between sprints of <40 s (Castagna et al., 2009). According to Barbero-Alvarez et al. (2008), who investigated the activity profile and match demands of an official futsal match using a video-based system (AV Master 98—Fast Multimedia), the distance covered during a match was 4,313 ± 2,139 m and the mean distance covered per minute of play was 117.3 ± 11.6 m. Moreover, the mean distances in walking (0.37–3.6 km·h^{-1}) and jogging (3.7–10.8 km·h^{-1}) were 397 m and 1,792 m, respectively, which represent 9 and 40% of the total mean distance covered. The mean distance in medium intensity activity (10.9–18 km·h^{-1}) was 1,232 m (i.e., 28.5% of total match), high-intensity running (18.1–25 km·h^{-1}) 571 m (13.7%), and sprinting ($\geq$25.1 km·h^{-1}) 348 m (8.9%) (Barbero-Alvarez et al., 2008). In a different study, professional futsal players tracked over five matches (i.e., using DVideo software automatic tracking system) (Bueno et al., 2014) were reported to cover a total distance of 3,133 m (2,248 interquartile ranges [IQRs]) for the whole match and a total relative distance of 97.9 ± 16.2 during the 1st half and 90.3 ± 12.0 m·min^{-1} during the 2nd. These values were somehow lower than the ones found by Castagna et al. (2009), which could be explained by the fact that, in the latter study, players completed a simulated futsal match comprising four sets of 10 min, with a 5 min rest (i.e., different from an official game). The dissimilarities in match characteristics may have allowed players to maintain higher levels of activity due to the shorter working period.

Examining the number of sprints performed during futsal competition, Caetano et al. (2015) observed, using a video automatic tracking system, that players execute 26 ± 13.3 sprints throughout the match. A more thorough analysis of the sprint demands noted that the most frequent repeated sprint actions comprised two consecutive sprints and a recovery of ~15 s. However, sequences of three and four sprints and rest intervals of 30, 45, or 60 s have also been reported. Considering playing position, there were no differences in sprint distance covered, peak velocity, initial velocity, recovery time between consecutive sprints, and number of sprints per min (Caetano et al., 2015). This could be explained not only by the tactical and technical characteristics of the sport (that make players more flexible to changing or rotating positions) but also by the unlimited number of substitutions or the possibility of playing with a "fly goalkeeper" during match-play.

Comparing the 1st and 2nd halves, a study with Brazilian elite players (Bueno et al., 2014) found that the percentage of distance covered standing and walking was higher in the 2nd half. Conversely, the distance covered at medium and high velocity and sprinting decreased significantly when compared to the 1st half (Bueno et al., 2014), which supported previous research (Barbero-Alvarez et al., 2008; Ribeiro et al., 2020). A related study (Milioni et al., 2016) confirmed that the total distance (1st half: 1,986 ± 74.4 m; 2nd half: 1,856 ± 129.7 m) and the distance covered by minute (1st half: 103.2 ± 4.4 m·min^{-1}; 2nd half: 96.4 ± 7.5 m·min^{-1}) decreased significantly from the 1st to the 2nd half but found no meaningful differences regarding the number of sprints or total sprinting time. Despite these inconsistencies, it appears that intensity tends to decrease as the match approaches the final minutes, which may be due not only to increased fatigue levels but also to tactical decisions (e.g., longer possessions or the utilization of a "fly goalkeeper") that "slow down" the game.

In an investigation analyzing international- and national-level futsal competition, Dogramaci et al. (2011) reported that elite teams covered a 42% greater total distance than sub-elite teams did (4,277 ± 1,030 m vs. 3,011 ± 999 m, respectively). Moreover, the former traveled a 58% greater jogging distance and covered a 93% higher distance while moving sideways or backward and completed a higher total number of activities (i.e., 468 ± 77 for elite; 306 ± 81 for sub-elite) (Dogramaci et al., 2011). Upon review of the included studies, it appears that elite futsal players perform more high-energy metabolic and

TABLE 1 | Summary of time-motion analysis and physiological responses.

Study	Participants (n^o)	VO_{2max}	Heart rate	Blood lactate ($mmol \cdot L^{-1}$)	Medium-intensity running	High-intensity running	Sprinting	Distance covered (m)
Barbero-Alvarez et al. (2008)	10	NR	174 ± 7 $b \cdot min^{-1}$ $90\% \pm 2^{d}$	NR	1232 m $28\% \pm 2.2^{c}$	571 m $13.7\% \pm 2.0^{c}$	348 m $8.9\% \pm 3.4^{c}$	4313 ± 2138
Bekris et al. (2020)	21	NR	$93\% \pm 2.5^{d}$	1st half: 14.86 ± 4.91 2nd half: 15.00 ± 4.67	NR	NR	NR	NR
Bueno et al. (2014)	93	NR	NR	NR	1st half: 16.4% (IQRs: 3.4)[c] 2nd half: 15.4% (IQRs: 3.4)[c]	1st half: 8.0% (IQRs: 2.4)[c] 2nd half: 7.5% (IQRs: 2.0)[c]	1st half: 7.6% (IQRs: 4.3)[c] 2nd half: 7.2% (IQRs: 2.7)[c]	3133 (IQRs: 2248)
Caetano et al. (2015)	97	NR	NR	NR	NR	NR	26 ± 13.3 SP	NR
Castagna et al. (2009)	8	76% (95% CI: 59–92)[a] 48.6 (95% CI: 40.1–57.1)[b] $ml \cdot kg^{-1} \cdot min^{-1}$	90% (95% CI: 84–96)[a]	5.3 (95% CI: 1.1–10.4)	NR	12% (95% CI: 3.8–12.9)[c]	5% (95% CI: 1–11.0)[c]	NR
Charlot et al. (2016)	10	NR	168 ± 8.6 $b \cdot min^{-1}$ $83.2\% \pm 2.3^{d}$	NR	NR	NR	NR	NR
Dogramaci and Watsford (2006)	8	NR	NR	NR	1521 ± 558 m	1105 ± 384 m	106 ± 59.9 m	4283 ± 808
Dogramaci et al. (2011)	8	NR	NR	NR	999 ± 333 m	NR	106 ± 56	4277 ± 1030
Makaje et al. (2012)	15	OF: $77.9\% \pm 9.0^{a}$ 43.7 ± 5.8^{b} $ml \cdot kg^{-1} \cdot min^{-1}$ GL: $63.2\% \pm 8.9^{a}$ 31.5 ± 4.7^{b} $ml \cdot kg^{-1} \cdot min^{-1}$	OF: 175 ± 12^{d} $b \cdot min^{-1}$ $89.8\% \pm 5.8^{d}$ GL: 147 ± 7^{d} $b \cdot min^{-1}$ $73.7\% \pm 5.1^{d}$	OF: 5.5 ± 1.4 GL: 4.2 ± 1.3	OF: 1050 ± 355 m GL: 196 ± 130 m	OF: 636 ± 248 m GL: 127 ± 85 m	OF: 422 ± 186 m GL: 110 ± 57 m	OF: 5087 ± 1104 GL: 2043 ± 702
Milanez et al. (2020)	85	NR	NR	NR	NR	NR	NR	3046 ± 1485
Milioni et al. (2016)	10	NR	1st half: 168.4 ± 12.4 $b \cdot min^{-1}$ 2nd half: 166.4 ± 12.5 $b \cdot min^{-1}$	1st half: 4.8 ± 2.3 2nd half: 4.2 ± 2.2	NR	NR	1st half: 49.5 ± 14.5 SP 2nd half: 45.5 ± 9.1 SP	1st half: 1986.6 ± 74.4 2nd half: 1856 ± 127.7
Ohmuro et al. (2020)	79	NR	NR	NR	$20\% \pm 2^{c}$	$11.3\% \pm 1.4^{c}$	$12\% \pm 3.1^{c}$	4151 ± 942^{e}
Ribeiro et al. (2020)	28	NR	NR	NR	1321.5 ± 479.8 m	675.3 ± 298.1 m	134.9 ± 54.1 m	3749 ± 1123

(Continued)

TABLE 1 | Continued

Study	Participants (n°)	VO_{2max}	Heart rate	Blood lactate ($mmol \cdot L^{-1}$)	Medium-intensity running	High-intensity running	Sprinting	Distance covered (m)
Rodrigues et al. (2011)	14	79.2% ± 9.0[a]	86.4% ± 3.8[d] 199 ± 8.5 $b \cdot min^{-1}$	NR	NR	NR	NR	NR
Yiannaki et al. (2020)	16	NR	87.7% ± 4.4[d] 164.8 ± 22.3 $b \cdot min^{-1}$	NR	NR	NR	NR	NR

Values expressed as mean ± SD.
[a]Mean game values with respect to maximal treadmill test values.
[b]Mean game values of VO_2.
[c]Percentage of total playing time.
[d]Mean game values as percentage of maximum heart rate.
$b \cdot min^{-1}$, beats per minute; CI, confidence interval; GL, goalkeepers; IQRs, interquartile ranges; m, meters; n°, number; NR, not reported; OF, outfield player; SP, number of sprints; VO_{2max}, maximum oxygen uptake.

mechanical activities during competition with shorter recovery times. Match-related fatigue may influence high-intensity efforts and sprinting time from the 1st to 2nd half. From an applied perspective, knowing the match demands, understanding the differences in performance between the two halves and between professional and semi-professional athletes could be helpful for strength and conditioning coaches and sport scientists. These data may assist in developing more adequate match-action-specific training strategies, thus enhancing performance and potentially reducing the risk of injury. Interestingly, only two studies (Ribeiro et al., 2020; Yiannaki et al., 2020) used wearable technology (i.e., GPS or accelerometry) during the games, highlighting the need for further research regarding the description of the external loads experienced by players during official competition.

Physiological Responses

Due to the frequent intermittent high-intensity actions that occur in most team-sports, researchers have long been interested in understanding the physiological stress imposed during the match by analyzing variables such as heart rate (HR), oxygen uptake (VO_2), or blood lactate concentration ([La]) (Spencer et al., 2005; Impellizzeri et al., 2006; Ostojic et al., 2006). Particularly in futsal, eight studies (Barbero-Alvarez et al., 2008; Castagna et al., 2009; Rodrigues et al., 2011; Makaje et al., 2012; Charlot et al., 2016; Milioni et al., 2016; Bekris et al., 2020; Yiannaki et al., 2020) have investigated the physiological responses during a match (**Table 1**).

Barbero-Alvarez et al. (2008) monitored the HR (Polar Vantage NV) of 10 players during four competitive futsal matches. The HR_{mean} was 174 ± 7 $b \cdot min^{-1}$ (range: 164–181), which represented 90 ± 2% (range 86–93) of HR_{max}. With HR being classified based on the percentage of time spent in different zones, players spent 0.3, 16, and 83% at intensities ≤65, 85–65, and ≥85% of HR_{max}, respectively. Other data from official matches, however, displayed slightly lower HR values (86.4 ± 3.8% HR_{max}) (Rodrigues et al., 2011). Comparing the two halves, different outcomes have been reported in the literature. On the one hand, a significant decrease in the percentage of time spent at an intensity ≥85% of HR_{max} was identified from the 1st to 2nd half (Barbero-Alvarez et al., 2008). On the other, no meaningful differences were found on HR_{max} (1st half: 186.9 ± 9.2 $b \cdot min^{-1}$; 2nd half: 185.7 ± 10.0 $b \cdot min^{-1}$) and HR_{mean} (1st half: 168.4 ± 12.4 $b \cdot min^{-1}$; 2nd half: 166.4 ± 12.5 $b \cdot min^{-1}$) (Milioni et al., 2016). According to Castagna et al. (2009), the mean HR_{max} achieved during a simulated futsal match corresponded to 90% of the maximal treadmill test values, with peak values reaching 98%. Based on these results, it appears that HR_{max} values during official competition are lower than the ones achieved in a simulated match (i.e., 4 × 10 min, with a 5 min intermission); however, more research is needed to clarify the differences between the 1st and 2nd halves.

Regarding VO_2, a study reported that the mean game values (measured with a portable gas analyzer) were 48.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (95% confidence intervals [95% CI]: 40.1–57.1 $ml \cdot kg^{-1} \cdot min^{-1}$) and that players spent 46% of the playing time (during a simulated match) at intensities higher than 80% of

VO_{2max} (Castagna et al., 2009). Moreover, the mean and peak values achieved during the modified game corresponded to 76 and 99%, respectively, of the VO_{2max} obtained in a maximal treadmill test (Castagna et al., 2009). When it comes to official competition data, an average intensity of 79.2 ± 9.0% of VO_{2max} was achieved in terms of oxygen consumption (Rodrigues et al., 2011). Concerning the accumulation of lactate ([La]), a $[La]_{mean}$ value of 5.3 (95% CI: 1.1–10.4) $mmol \cdot L^{-1}$ was reported after the previously mentioned simulated match investigated by Castagna et al. (2009). Interestingly, and following the same pattern observed in the other variables (i.e., HR and VO_{2max}), this value was higher than official games, in which $[La]_{mean}$ (analyzed by an electrochemical lactimeter YSI 1500) of 4.8 ± 2.3 $mmol \cdot L^{-1}$ (1st half) and 4.2 ± 2.2 $mmol \cdot L^{-1}$ (2nd half) were found (Milioni et al., 2016). Conversely, Bekris et al. (2020), using a portable blood analyzer, displayed higher values of $[La]_{mean}$ (1st half: 14.9 ± 4.9 and 2nd half: 15.0 ± 4.7) as the assessment was performed throughout the match, when the player was taken out.

The knowledge about the physiological demands of futsal is of paramount importance since it offers information concerning the stress imposed upon the players during competition. The average intensity of effort during the matches is high (mainly ≥85% of HR_{max}) with an important decrement of high-intensity efforts between the two halves.

Neuromuscular Responses

High-intensity efforts (e.g., sprinting, jumping, and changes of direction [COD]) play a significant role in team-sports. Several studies indicate that stronger and more powerful players (i.e., with better-developed neuromuscular capabilities) of different sports are prone to accelerate faster, jump higher, and change direction more rapidly (Newton et al., 2006; Loturco et al., 2016b; Freitas et al., 2019). Moreover, it has been shown that sport-specific activities such as kicking or tackling are also influenced by the ability of an athlete to generate greater levels of force and power (Marques et al., 2007; Loturco et al., 2016a). With this in mind, four studies (Caetano et al., 2015; Milioni et al., 2016; Milanez et al., 2020; Ribeiro et al., 2020) investigated the neuromuscular outcomes during and after a futsal match.

Of note, apart from the increases in sprint time from the 1st to 2nd half discussed above, important alterations in neuromuscular function have been identified after a futsal match (Caetano et al., 2015; Ribeiro et al., 2020). Particularly, decrements in peak force and voluntary activation (i.e., manifestations of fatigue) were present following match-play; moreover, these were significantly associated with a reduction in running actions (i.e., repeated high-intensity efforts and sprints) (Milioni et al., 2016). Nevertheless, future studies are necessary to better elucidate the mechanisms (i.e., if peripheral or central in origin) impairing performance and the time-course of recovery (i.e., when do values get back to pre-competition levels) following a futsal match. Therefore, coaches and strength and conditioning specialists are advised to closely monitor the training and competition load and promote post-match recovery strategies to minimize injury risk and to potentially maintain players' peak neuromuscular performance throughout the season and during match-congested periods.

Biochemical Responses

To better understand the actual futsal match-play demands, and following a more holistic approach to the study of the stress imposed by competition, some researchers have investigated different biochemical markers post-game. Particularly, three studies (Moreira et al., 2011; de Moura et al., 2013; Bekris et al., 2020) have focused on this topic. A biomarker associated with responses to exercise is the salivary immunoglobulin A (SIgA), and when decreased, its concentration may be a good marker of excessive training (Petersen and Pedersen, 2005). Moreira et al. (2011) collected unstimulated saliva samples to investigate the SIgA responses in professional futsal players and observed a decline in absolute concentration, secretion rate, and saliva flow following a futsal match, which proposes a general risk for respiratory tract infection incidence. Hence, according to the authors' recommendations, actions should be held to minimize contact with virus or reduce training load under such conditions. Bekris et al. (2020) examined the biochemical and metabolic responses as well as the muscle damage induced by futsal competition and identified increased creatine kinase (CK) levels and a reduced testosterone/cortisol ratio after the game from blood samples collected from the forearm vein.

As it could be expected, given that different positions have different demands and characteristics (Baroni and Leal Junior, 2010; Ramos-Campo et al., 2014), dissimilar stress levels occur in the biochemical and immune systems. Goalkeepers have been reported to have a significantly higher lactate dehydrogenase concentration and IL-6 when compared to on-court players after the match; however, no differences in serum CK were obtained among positions (de Moura et al., 2013). In practical terms, results from the literature suggest that futsal competition promotes a decrease of plasma SIgA, increased muscle soreness, CK levels at post and post 24 h, and different stress responses among positions. These findings should be considered by coaches, strength and conditioning professionals, and nutritionists in order to maximize athletes' performance. Useful strategies may be the utilization of different techniques to avoid overreaching in futsal players; for instance, antioxidant supplement, omega-3 fatty acid, and anti-inflammatory drug intake, as well as reducing the training load.

Player Characteristics

Anthropometrics

Anthropometric characteristics (i.e., height, body mass, and body composition) are important components of physical fitness as it is well-accepted that, for example, excessive body fat can potentially impair performance in team-sports (Vila Suárez et al., 2008). Conversely, a greater percentage of muscle skeletal mass tends to increase sport performance as it contributes to energy production during high-intensity activities and enhances athletes' force production capabilities (Vila Suárez et al., 2008). In this context, several studies have investigated the anthropometric characteristics of futsal players with the database search yielding 10 articles (Baroni and Leal Junior, 2010; Gomes et al., 2011; Jovanovic et al., 2011; Garrido-Chamorro et al., 2012; de Moura et al., 2013; Pedro et al., 2013; Ramos-Campo et al., 2014; Galy et al., 2015; Nikolaidis et al., 2019; López-Fernández et al., 2020).

In general, elite futsal players have been reported to weigh, on average, ∼70 kg, to measure ∼1.76 m of height and to display ∼15% of body fat (Jovanovic et al., 2011; Garrido-Chamorro et al., 2012).

Investigations comparing elite players with their sub-elite counterparts found no significant differences in anthropometric characteristics (Pedro et al., 2013; López-Fernández et al., 2020). For example, López-Fernández et al. (2020) found similar fat mass between elite and sub-elite players. However, elite players demonstrated higher lean mass in the dominant and non-dominant legs when compared to lower-level players; moreover, the latter showed higher bilateral asymmetry in fat mass percentage. No meaningful differences were found between professional and semi-professional players in a sample of Brazilian futsal players (Pedro et al., 2013). Therefore, it is still unknown to what extent height and body mass may be adequate variables to discriminate athletes from different competition levels.

Regarding playing position, research indicates significant differences on anthropometric characteristics (Baroni and Leal Junior, 2010; Ramos-Campo et al., 2014). In a study comparing body fat percentage among positions, pivots presented the highest value, followed by goalkeepers, backs, and, lastly, wingers (Ramos-Campo et al., 2014). In contrast, a different investigation (de Moura et al., 2013) found that goalkeepers were slightly taller and heavier and had a higher percentage of body fat (1.78 ± 3.2 cm, 74 ± 2.5 kg, 13 ± 2%, respectively) than defenders (1.74 ± 1 cm, 69 ± 2 kg, 10 ± 2%), wingers (1.69 ± 3 cm, 68 ± 2 kg, 11 ± 2%), and pivots (1.73 ± 2 cm, 71 ± 2 kg, 10 ± 2%). Similar results were found by Baroni and Leal Junior (2010), who indicated that the 22 goalkeepers comprised in the study's sample were significantly heavier and taller than their 164 on-court counterparts. The lack of significant differences in body fat among on-court players could be explained by the fact that, in futsal, playing positions are highly variable during the game because of the tactical behaviors that require players to perform multiple positional demands in order to adapt to the team's tactical system. It should be highlighted, however, that it is not clear whether the higher body mass reported for goalkeepers consists of fat or muscle mass. Given the paucity of data and lack of clear reporting, further research is required to better clarify the positional differences in anthropometric characteristics of futsal players.

In summary, according to the literature, futsal players display a low percentage of fat, which seems to be commonplace among players from different playing on-court positions and different competitive levels. This information may be important to adjust training programs and should be considered on young talent-detection practices.

Physiological Characteristics

The aerobic energy system has a crucial role in futsal match-play since it is well-established that this system improves recovery after high-intensity exercise (Helgerud et al., 2001; Tomlin and Wenger, 2001). Futsal players perform around 4 km in a match, with frequent bouts of repeated sprints, ACC, and DEC with short recovery times, which supports the importance of a well-developed aerobic energy system (Barbero-Alvarez et al., 2008; Ribeiro et al., 2020). In addition, as reported above, players achieve mean and peak VO_2 values during competition which correspond to their 76 and 99% of VO_{2max}, respectively. Upon review, 31 studies (Barbero-Alvarez et al., 2009; Gorostiaga et al., 2009; Baroni and Leal Junior, 2010; Castagna and Barbero-Alvarez, 2010; Milanez et al., 2011; Makaje et al., 2012; Boullosa et al., 2013; Oliveira et al., 2013; Pedro et al., 2013; Cuadrado-Peñafiel et al., 2014; Miloski et al., 2014; Soares-Caldeira et al., 2014; De Freitas et al., 2015, 2019; Galy et al., 2015; Garcia-Tabar et al., 2015; Charlot et al., 2016; Floriano et al., 2016; Nakamura et al., 2016, 2018; Naser and Ali, 2016; Barbieri et al., 2017; Barcelos et al., 2017; Valladares-Rodriguez et al., 2017; Nogueira et al., 2018; Zarebska et al., 2018, 2019; Farhani et al., 2019; Nikolaidis et al., 2019; Teixeira et al., 2019; Wlodarczyk et al., 2019, 2020; Bekris et al., 2020) have looked at the physiological characteristics of elite futsal players (**Table 2**).

Considering competition level, elite and sub-elite players display dissimilar aerobic capacities (Barbero-Alvarez et al., 2009; Makaje et al., 2012; Pedro et al., 2013; Naser and Ali, 2016; Farhani et al., 2019). For example, VO_{2max} values of 62.9 ± 5.3 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ were reported for elite vs. 55.2 ± 5.7 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ for sub-elite athletes. Moreover, elite players presented a VO_2 at a ventilatory anaerobic threshold (VT_2) of 44.4 ± 4.6 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ while sub-elite displayed 39.1 ± 4.0 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ (Barbero-Alvarez et al., 2009). Interestingly, a study found no significant differences in VO_{2max} and VO_2 at VT_2 (in an incremental test in which players used a gas analyzer) but reported that the speed at VT_2 (S_{vt2}) and speed at VO_{2max} (S_{Vo2max}) were significantly higher in elite players when compared to their sub-elite counterparts (S_{vt2}: 11.2 ± 1.0 vs. 10.0 ± 1.2 $km{\cdot}h^{-1}$; S_{Vo2max}: 17.5 ± 0.9 vs. 15.2 ± 1.0 $km{\cdot}h^{-1}$) (Pedro et al., 2013). Similar results were found elsewhere, when comparing elite, sub-elite, and social futsal players, using the distance covered in the Futsal Intermittent Endurance Test (FIET) (Naser and Ali, 2016). Elite players covered a greater distance (1,378 ± 228 m) in relation to sub-elite (1,018 ± 133 m) and social players (781 ± 220 m) (Naser and Ali, 2016).

A detailed look at the published studies portrays that different kinds of tests have been used to assess aerobic performance in futsal (e.g., Yo-Yo IR1–IR2, FIET, 30-15 Intermittent Fitness Test, Futsal Circuit, and Carminatti's test) and that fitness field tests may be useful to evaluate the aerobic capacity on elite players (Castagna and Barbero-Alvarez, 2010; Boullosa et al., 2013; Garcia-Tabar et al., 2015; Floriano et al., 2016; Barbieri et al., 2017; Valladares-Rodriguez et al., 2017). For example, a study by Nakamura et al. (2016) showed that Brazilian elite players covered 1,500 ± 287 m in the Yo-Yo IR1 test whereas a sample of under-20 players completed only 1,264.0 ± 397.9 m. Thus, it appears that such type of protocols may differentiate athletes from different age categories. A practical way to apply these field tests is through their implementation as part of the training routine as they may be equally useful for training purposes and performance monitoring. Moreover, the tests are inexpensive and need little equipment and few resources and player

TABLE 2 | Summary of physiological characteristics.

Study	Participants (n°)	Level	Test	Test-specific outcome	VO_{2max} (ml·kg^{-1}·min^{-1})	HR_{max} (b·min^{-1})	VT_2 (ml·kg^{-1}·min^{-1})	Blood lactate (mmol·L^{-1})
Barbero-Alvarez et al. (2009)	11	Elite	TM	N/A	62.9 ± 5.3	191 ± 8	44.4 ± 4.6	12 ± 2.5
	13	Sub-Elite			55.2 ± 5.7	198 ± 13	39.1 ± 4.0	7.8 ± 1.6
Barbieri et al. (2017)	16	Elite	Futsal_circuit	N/A	NR	198.5 ± 8	NR	7.87 ± 0.7
Barcelos et al. (2017)	8	Elite	Yo-Yo IR2	764.4 ± 206.7 m	55.7 ± 2.8	184.5 ± 12.2	NR	NR
Baroni and Leal Junior (2010)	186	Elite	TM	N/A	58 ± 6.37	190.14 ± 8.42	51.25 ± 5.84	NR
Bekris et al. (2020)	21	Elite	Yo-Yo IR2	N/A	65.17	193.0 ± 8.39	NR	NR
Boullosa et al. (2013)	15	Elite	TM	N/A	57.25 ± 6.35	184 ± 5	NR	NR
	15		Yo-Yo IR1		NR	184 ± 15		8.17 ± 1.63
Castagna et al. (2009)	18	Elite	TM	N/A	65.1 ± 6.2	193 ± 2	45.2 ± 4.6	12.6 ± 2.3
	18		RET		61.6 ± 4.6	191 ± 7	NR	12.6 ± 2.3
Charlot et al. (2016)	10	Elite	30-15IFT	19.2 ± 0.6 km·h^{-1}	53.1 ± 2.1	NR	NR	NR
Cuadrado-Peñafiel et al. (2014)	12	Elite	TM	N/A	62.95 ± 5.21	NR	NR	NR
De Freitas et al. (2015)	10	Elite	Yo-Yo IR1	1433 ± 344^a m	NR	198.4 ± 7.3^a	NR	NR
De Freitas et al. (2019)	10	Elite	RET	16.6 ± 0.3 km·h^{-1}	NR	NR	NR	NR
Farhani et al. (2019)	18	Elite	FSPT	770.2 ± 34.6W 30.08 ± 1.77 s	NR	NR	NR	NR
	18	Sub-Elite		714.5 ± 34W 35.45 ± 1.59 s				
Foriano et al. (2016)	10	Elite	TM		49.06 ± 4.7	185 ± 11	NR	8.5 ± 2.1
	10		T-CAR		51.1 ± 4.7	189 ± 9		13.6 ± 2.4
Galy et al. (2015)	22	Elite	30-15IFT	MEL-G: 18.71 ± 1.33 km·h^{-1} NMEL-G: 19.5 ± 0.6 km·h^{-1}	MEL-G: 51.46 ± 3.2 NMEL-G: 52.74 ± 1.94	MEL-G: 193.56 ± 8.26 NMEL-G: 187.88 ± 12.68	NR	NR
Garcia-Tabar et al. (2015)	10	Elite	SRT	N/A	NR	192 ± 5	NR	10 km·h^{-1}: 1.5 ± 0.4 12 km·h^{-1}: 2.0 ± 0.6 14 km·h^{-1}: 4.4 ± 1.2
Gorostiaga et al. (2009)	15	Elite	SRT	N/A	NR	13 km·h^{-1}: 170.7 ± 8 14 km·h^{-1}: 179.9 ± 6 15 km·h^{-1}: 183.5 ± 5	NR	13 km·h^{-1}: 4.2 ± 2.0 14 km·h^{-1}: 6.4 ± 2.1 15 km·h^{-1}: 6.2 ± 1.7
Makaje et al. (2012)	15 15	Elite Sub-Elite	TM/ Yo-Yo IR2	OF: 1558 ± 451 m GL: 900 ± 403 m OF: 1203 ± 660 m GL: 726 ± 316 m	OF: 60.4 ± 5.1 GL: 54.6 ± 5.7 OF: 57.2 ± 6.2 GL: 52.4 ± 3.5	NR	NR	NR

(Continued)

TABLE 2 | Continued

Study	Participants ($n°$)	Level	Test	Test-specific outcome	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR_{max} ($b \cdot min^{-1}$)	VT_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	Blood lactate ($mmol \cdot L^{-1}$)
Milanez et al. (2011)	9	Elite	TM	N/A	59.6 ± 2.5	190.4 ± 6.4	42.2 ± 6.0	NR
Miloski et al. (2014)	12	Elite	Yo-Yo IR2	450 ± 95.2[a] m	48.6 ± 3.9[a]	NR	NR	NR
Miloski et al. (2016)	12	Elite	MSRT	N/A	49.5 ± 3.5[a]	NR	NR	NR
Nakamura et al. (2016)	18	Elite	Yo-Yo IR1	1506.7 ± 287.1 m	NR	NR	NR	NR
Nakamura et al. (2018)	11	Elite	Yo-Yo IR1	1160 ± 472.61 m	NR	NR	NR	NR
Naser and Ali (2016)	8	Elite	RET	1378 ± 228.1 m	NR	NR	NR	NR
	8	Sub-Elite		1018.1 ± 133.8 m				
Nikolaidis et al. (2019)	16	Elite	MSRT	1020 ± 1:20 min	NR	192.2 ± 6.9	NR	NR
Nogueira et al. (2018)	15	Elite	Yo-Yo IR2	573.3 ± 193.4[a] m	NR	NR	NR	NR
Oliveira et al. (2013)	15	Elite	Yo-Yo IR1	1244 ± 298[a] m	NR	NR	NR	NR
Pedro et al. (2013)	9	Elite	TM		63.7 ± 4.1	189 ± 7	43.0 ± 4.1	NR
	11	Sub-Elite	TM	N/A	62.1 ± 4.4	204 ± 11	44.0 ± 3.8	
Soares-Caldeira et al. (2014)	6	Elite	Yo-Yo IR1	1280 ± 363[a] m	NR	NR	NR	NR
	7	Elite		1291 ± 363[a] m				
Teixeira et al. (2019)	28	Elite	RET	15.89 ± 1 $km \cdot h^{-1}$	NR	NR	NR	NR
Valladares-Rodriguez et al. (2017)	13	Elite	30-15IFT	20.2 ± 1.7 $km \cdot h^{-1}$	NR	189 ± 7	NR	NR
Wlodarczyk et al. (2019)	12	Elite	TM	N/A	57.53 ± 1.1	187.50 ± 10	38.45 ± 3.9	10.9 ± 1.2
Wlodarczyk et al. (2020)	12	Elite	TM	N/A	56.14 ± 3.1[a]	187.09 ± 10.3[a]	37.69 ± 4.2[a]	11 ± 2.1[a]
Zarebska et al. (2018)	14	Elite	TM	N/A	56.66 ± 2.62	187 ± 10	NR	11.4 ± 2
Zarebska et al. (2019)	11	Elite	TM	N/A	55.81 ± 3.94[a]	192.7 ± 7[a]	NR	11.6 ± 2.2[a]

Values expressed as mean ± SD.

[a]*Pre-intervention values.*

$b \cdot min^{-1}$, beats per minute; FIET, futsal intermittent endurance test; FSPT, futsal special performance test; GL, goalkeeper; HR_{max}, maximum heart rate; MSRT, multistage 20m shuttle-run test; MEL-G, Melanesians group; NMEL-G, non-Melanesians group; n°, number; N/A, not applicable; NR, not reported; OF, outfield players; SRT, submaximal running test; T-CAR, Carminatti's test; TM, treadmill test; VO_{2max}, maximum oxygen uptake; VT_2, ventilator anaerobic threshold; Yo-Yo IR1, Yo-Yo intermittent recovery test level 1; Yo- Yo IR2, Yo- Yo intermittent recovery test level.

motivation could be increased when tests are completed with the ball.

The present findings suggest that physiological capacities may help discriminate superior-level futsal players since elite competitors display slightly higher VO_{2max} and VT_2 values and obtain superior scores in different field tests in comparison with their sub-elite counterparts. Moreover, on-court players have greater aerobic capacity when compared to goalkeepers. Strength and conditioning coaches and sport scientists should focus on designing training drills that favor the improvement of the aerobic capacity to prepare players to cope with the demands of match-play.

Neuromuscular Characteristics

Strength capability

Strength and power capabilities are key components in most team-sports. Several studies have presented that stronger and more powerful players of different modalities tend to be faster, have better COD ability, and jump higher (Wilson et al., 1993; Newton et al., 2006; Freitas et al., 2019). In this context, four studies (Cuadrado-Peñafiel et al., 2014; Vieira et al., 2016; De Lira et al., 2017; Nunes et al., 2018) investigated the strength capabilities of futsal players (**Table 3**). Utilizing an isokinetic dynamometer, different authors (Vieira et al., 2016; De Lira et al., 2017; Nunes et al., 2018) assessed elite futsal players' strength levels by reporting peak torque values of the quadriceps and hamstrings. De Lira et al. (2017) reported that peak torque values at $60°·s^{-1}$ of the dominant leg were 223.9 ± 33.4 N·m for the quadriceps and 128 ± 27.6 N·m for the hamstrings, while the non-dominant leg displayed values of 224 ± 35.8 N·m and 124.1 ± 20.1 $N·m^{-1}$ for the knee extensors and flexors, respectively. The H/Q ratio was 0.58 ± 0.1. Interestingly, when the mixed H/Q ratio (i.e., hamstrings eccentric angular velocity of $30°·s^{-1}$ and quadriceps concentric velocity of $240°·s^{-1}$) was assessed in the preferred and non-preferred limbs of 40 players, significant contralateral differences were found on knee flexors' eccentric contractions and in the H/Q ratio in favor of the preferred limb (Nunes et al., 2018). Only one study assessed the one repetition-maximum (1RM) on the half-squat exercise in order to characterize futsal players' strength qualities (1RM: 94.73 ± 17.01 kg) (Cuadrado-Peñafiel et al., 2014).

Considering the previous, more research is clearly needed to investigate the force production capabilities of futsal athletes, as the vast majority of research utilized isokinetic dynamometry. Accordingly, the dominant leg seems to be stronger (i.e., reach higher peak torque values) than the non-dominant leg. Based on this information, strength and conditioning specialists should be aware that unilateral strength testing may be necessary to allow preparing specialized and tailored training plans to maximize lower-body strength and attenuate the likelihood of injuries. However, given that isokinetic testing is extremely time-consuming, expensive, and not practical to use in real-world scenarios, other exercises (e.g., half-squat, split squat, hip-thrust, or deadlift, isometric tests) should be implemented when assessing lower-body strength.

Jumping ability

Data from futsal competition indicates that players perform multiple high-intensity efforts (i.e., jumping, sprinting, or COD) (Caetano et al., 2015; Ribeiro et al., 2020). For that reason, and considering that lower-body powerful actions are determinant during the match, several researchers have investigated power-related capacities of futsal players. Particularly, 14 studies (Gorostiaga et al., 2009; Gomes et al., 2011; Cuadrado-Peñafiel et al., 2014; Soares-Caldeira et al., 2014; Galy et al., 2015; Miloski et al., 2016; Nakamura et al., 2016; Naser and Ali, 2016; Loturco et al., 2018; Nogueira et al., 2018; De Freitas et al., 2019; Nikolaidis et al., 2019; Teixeira et al., 2019; Nunes et al., 2020) assessed elite futsal players' jumping ability (**Table 3**). For example, an investigation with 63 professional players reported jump heights (measured with a contact mat) of 37.8 cm in the squat jump and 38.5 cm in the countermovement jump (CMJ) as well as bar mean propulsive and peak power outputs of 9.2 and 20.4 $W·kg^{-1}$, respectively (Loturco et al., 2018). Similar values for the CMJ were reported elsewhere (Gorostiaga et al., 2009).

Considering the different levels of futsal players, Naser and Ali, 2016 identified no significant differences in CMJ height between elite and sub-elite futsal players. Despite the need for players to execute vertical jump actions during futsal competition, it seems that these may be less determinant for performance when compared to other sports, such as soccer. Based on the studies that have assessed vertical jump height, it appears that elite futsal players do not display greater jumping ability than their sub-elite counterparts, potentially due to the limited influence of jumping ability in the game. However, it has been shown that the successful application of vertical ground reaction forces (i.e., as in vertical jumping) may play a significant role in multiple athletic actions (e.g., sprinting or COD) (Loturco et al., 2019). For this reason, strength and conditioning coaches are encouraged to include multiple bilateral and unilateral jumping tasks in their training programs to maximize lower-body power and, consequently, performance of elite futsal players.

Sprinting ability

Data from match demands demonstrates that futsal players perform ~26 sprints with an average duration of 2–4 s over 8–20 m (Caetano et al., 2015). Considering that, several authors (Gorostiaga et al., 2009; Galy et al., 2015; Charlot et al., 2016; Miloski et al., 2016; Nakamura et al., 2016; Naser and Ali, 2016; Loturco et al., 2018, 2020; De Freitas et al., 2019; Jiménez-Reyes et al., 2019; Nikolaidis et al., 2019; Sekulic et al., 2019; Teixeira et al., 2019; Nunes et al., 2020) investigated the sprint performance of futsal players (**Table 3**). Loturco et al. (2018) utilized photocells to examine sprint capabilities and found velocities (i.e., average velocity derived from time and distance) of 4.81 ± 0.25 $m·s^{-1}$ (5 m), 5.68 ± 0.19 $m·s^{-1}$ (10 m), and 6.61 ± 0.22 $m·s^{-1}$ (20 m) in elite futsal players. Regarding acceleration ability (i.e., calculated as the rate of change of velocity with respect to time), the same study reported values of 4.64 ± 0.50 $m·s^{-2}$ for 0–5 m, 1.22 ± 0.22 $m·s^{-2}$ for 5–10 m, and 0.74 ± 0.09 $m·s^{-2}$ for 10–20 m. Gorostiaga et al. (2009) assessed 5 and 15 m sprint times (not velocities) of 15 players (using photocell gates) and found values of 1.01 ± 0.02 and 2.41 ± 0.08 s, respectively.

TABLE 3 | Summary of neuromuscular characteristics.

Study	Participants (n°)	Level	Strength	Jump (cm)	Sprint	COD (°)
Charlot et al. (2016)	10	Elite	NR	NR	5 m: 1.00 ± 0.07 s 10 m: 1.72 ± 0.07 s 15 m: 2.38 ± 0.05 s 30 m: 4.20 ± 0.11 s	NR
Cuadrado-Peñafiel et al. (2014)	12	Elite	1RM Squat: 94.73 ± 17.01 kg	CMJ: 35.9 ± 5.29	NR	NR
De Freitas et al. (2019)	10	Elite	NR	SJ: 34.6 ± 3.9[a] CMJ: 36.6 ± 4.1 [a]	15 m: 2.43 ± 0.12[a] s	NR
De Lira et al. (2017)	30	Sub-Elite	60°·s^{-1} (N·m) Ext Dom: 223.9 ± 33.4 Ext N-Dom: 224 ± 35.8 Flex Dom: 128 ± 27.6 Flex N-Dom: 124.1 ± 20.1	NR	NR	NR
Galy et al. (2015)	22	Elite	NR	MEL-G: CMJ: 50.44 ± 5.88 NMEL-G: CMJ: 45.16 ± 4.34	MEL-G: 5 m: 1.41 ± 0.11 s 10 m: 2.18 ± 0.12 s 15 m: 2.82 ± 0.15 s 30 m: 4.72 ± 0.17 s NMEL-G: 5 m: 1.35 ± 0.08 s 10 m: 2.13 ± 0.13 s 15 m: 2.84 ± 0.12 s 30 m: 4.80 ± 0.15 s	T-Test (90/180°): MEL-G: 10.47 ± 0.58 s NMEL-G: 11.01 ± 0.64 s
Gomes et al. (2011)	92	Elite	NR	SJ: 36.74 ± 4.28 37.42 ± 4.86 36.61 ± 5.28 CMJ: 38.88 ± 4 39.72± 5.08 38.48 ± 4.80	NR	NR
Gorostiaga et al. (2009)	15	Elite	NR	CMJ: 38.1 ± 4.1	5 m: 1.01 ± 0.02 s 15 m: 2.41 ± 0.08 s	NR
Jiménez-Reyes et al. (2019)	39	Elite	NR	NR	5 m: 1.36 ± 0.04 s 20 m: 3.36 ± 0.09 s	NR
	10	Sub-Elite			5 m: 1.40 ± 0.02 s 20 m: 3.46 ± 0.04 s	
Loturco et al. (2018)	63	Elite	NR	SJ: 37.82 ± 7.10 CMJ: 38.50 ± 4.88	5 m: 4.81 ± 0.25 m·s^{-1} 10 m: 5.68 ± 0.19 m·s^{-1} 20 m: 6.61 ± 0.22 m·s^{-1}	Zig-zag (100°): 3.52 ± 0.11 m·s^{-1}
Loturco et al. (2020)	62	Elite	NR	NR	5 m: 4.79 ± 0.22 m·s^{-1} 10 m: 5.67 ± 0.23 m·s^{-1} 20 m: 6.62 ± 0.25 m·s^{-1}	Zig-zag (100°): 3.52 ± 0.16 m·s^{-1} COD-Def zig-zag (100°): 3.09 ± 0.25 m·s^{-1}
Miloski et al. (2016)	12	Elite	NR	CMJ: 47.5 ± 5.5[a]	5 m: 1.10 ± 0.08[a] s 20 m: 3.14 ± 0.11[a] s	T-Test 90/180°: 9.24 ± 0.31[a] s
Nakamura et al. (2016)	18	Elite	NR	SJ: 37.75 ± 3.93 CMJ: 39.22 ± 4.42	5 m: 1.05 ± 0.04 s 10 m: 1.78 ± 0.06 s 20 m: 3.05 ± 0.10 s	Zig-zag (100°): 5.71 ± 0.22 s
Naser and Ali (2016)	8	Elite	NR	CMJ: 52.1 ± 4.2	5 m: 1.00 ± 0.04 s 10 m: 1.75 ± 0.03 s 20 m: 2.99 ± 0.04 s	NR
	8	Sub-Elite		CMJ: 49.9 ± 3.9	5 m: 1.06 ± 0.02 s 10 m: 1.78 ± 0.01 s 20 m: 3.05 ± 0.04 s	
Nikolaidis et al. (2019)	16	Elite	NR	ABK: 38.9 ± 6.1	10 m: 1.85 ± 0.12 s 20 m: 3.18 ± 0.17 s	NR
Nogueira et al. (2018)	15	Elite	NR	SJ: 36.31 ± 4.08[a] CMJ: 40.11 ± 4.73[a] DJ: 38.33 ± 4.75 [a]	NR	NR

(Continued)

TABLE 3 | Continued

Study	Participants (n°)	Level	Strength	Jump (cm)	Sprint	COD (°)
Nunes et al. (2018)	40	Elite	60°·s^{-1} (N·m) Ext Pref: 214.7 ± 49.6 Ext N-Pref: 216.5 ± 51.6 Flex Pref: 136.6 ± 31.7 Flex N-Pref: 135.8 ± 3 240°·s^{-1} (N·m) Ext Pref: 178.1 ± 53.16 Ext N-Pref: 176.8 ± 52 Flex Pref: 124.3 ± 40.3 Flex N-Pref: 115.9 ± 38.1 30°·s^{-1} Ecc (N·m) Ext Pref: 296 ± 75.7 Ext N-Pref: 277.2 ± 73 Flex Pref: 173.5 ± 35.8 Flex N-Pref: 162.9 ± 40.8 120°·s^{-1} Ecc (N·m) Ext Pref: 299.3 ± 66.4 Ext N-Pref: 277.3 ± 66.1 Flex Pref: 185.7 ± 35.8 Flex N-Pref: 172.7 ± 58	NR	NR	NR
Nunes et al. (2020)	20	Elite	NR	SJ: 36.6 ± 3.2[a] 35.7 ±3.6[a] CMJ: 39.4 ± 3.4[a] 38.6 ± 3.9	5 m: 1.07 ± 0.04[a] s 1.06 ± 0.05[a] s 10 m: 1.39 ± 0.04[a] s 1.37 ± 0.05[a] s 15 m: 2.52 ± 0.06[a] s 2.52 ± 0.10[a] s	NR
Sekulic et al. (2019)	12	Elite	NR	NR	10 m: 1.63 ± 0.07 s	CODS_DD (38°): 2.39 ± 0.19 s CODS_DND 38°): 2.57 ± 0.16 s CODS_TD 38°): 2.03 ± 0.11 s COD_TND 38°): 2.31 ± 0.12 s
	20	Sub-Elite			10 m: 1.69 ± 0.11 s	CODS_DD (38°): 2.57 ± 0.22 s CODS_DND 38°): 2.65 ± 0.15 s CODS_TD 38°): 2.08 ± 0.14 s COD_TND 38°): 2.23 ± 0.10 s
Soares-Caldeira et al. (2014)	6	Elite	NR	SJ: 33.13 ± 5.76 CMJ: 38.82 ± 6.39	NR	NR
	7	Elite		SJ: 34.47 ± 2.50 CMJ: 42.77 ± 2.78		
Teixeira et al. (2019)	28	Elite	NR	SJ: 34.42 ± 4.15[a] CMJ: 35.37 ± 3.65 [a]	5 m: 4.75 ± 0.46[a] m·s^{-1} 15 m: 6.21 ± 0.37[a] m·s^{-1}	NR
Vieira et al. (2016)	17	Elite	60°·s^{-1} (N·m) Ext Dom: 253.31 ± 33.81 Ext N-Dom: 244.83 ± 24.78 180°·s^{-1} (N·m) Ext Dom: 184.04 ± 18.84 Ext N-Dom: 182.86 ± 20.17 300°·s^{-1} (N·m) Ext Dom: 138.59 ± 17.27 Ext N-Dom: 142.33 ± 18.77	NR	NR	NR

Values expressed as mean ± SD.

[a]*Pre-intervention values.*

ABK, Abalakov jump test; cm, centimeter; CMJ, countermovement jump test; COD, change of direction; COD-Def, change of direction Deficit; CODS_DD, change of direction dominant leg with ball; CODS_DND, change of direction of non-dominant leg with ball; CODS_TD, change of direction of dominant leg without ball; CODS_TND, change of direction of non-dominant leg without ball; Dom, dominant leg; Ecc, eccentric; Ext, extensor; Flex, flexor; HJ, horizontal jump test; L, left leg; MEL-G, Melanesians group; NMEL-G, non-Melanesians group; n°, number; N-Dom, non-dominant leg; N-Pref, non-preferred leg; NR, not reported; Pref, preferred leg; R, right leg; s, seconds.

Regarding competition level, a training approach based on the force–velocity profile found that 1st-Division futsal players sprinted 5 m in 1.36 ± 0.04 s and 20 m in 3.36 ± 0.09 s while 2nd-Division players demonstrated lower sprint performances (5 m: 1.40 ± 0.02 s; and 20 m: 3.46 ± 0.04 s) (Jiménez-Reyes et al., 2019). Along the same lines, other studies (Naser and Ali, 2016; Sekulic et al., 2019) observed that elite futsal players run faster over 5, 10, and 20 m than sub-elite or social players.

From the above information, it appears that elite players tend to display higher sprinting ability when compared to their sub-elite peers, although further research is necessary. Nevertheless, given that the majority of the published literature indicates that higher-level players tend to be faster, short sprints should be seen as an important training stimulus that may enhance the players' ability to succeed at superior competition levels, where match demands are greater.

Change of direction ability and agility

COD is one of most important efforts in futsal due to the rapid changes of activity during the match. COD relies on a series of anthropometric (e.g., height, leg length), physical (e.g., lower-body and trunk muscular strength, speed-power-related capabilities), and technical aspects (e.g., stride adjustments, foot placement) (Jeffreys, 2008; Pereira et al., 2018). In this context, six investigations (Galy et al., 2015; Miloski et al., 2016; Nakamura et al., 2016; Loturco et al., 2018, 2020; Sekulic et al., 2019) have performed an in-depth analysis of this paramount ability in futsal players (**Table 3**). In a study that examined COD performance on different sports, including futsal, players performed a zig-zag test consisting of four 5 m sections marked with cones set at 100° angles. The results found that futsal players obtained a COD velocity of 3.52 ± 0.11 $m \cdot s^{-1}$ (Loturco et al., 2018). When a complementary investigation from the same research group assessed the "COD deficit" (i.e., the difference in velocity between a linear sprint and a COD task of equivalent distance) for the first time in futsal, players from this modality were found to be more efficient than soccer players at changing direction but displayed COD deficits similar to other team-sports (i.e., rugby and handball players) (Loturco et al., 2020). Of note, a unique investigation (Sekulic et al., 2019) designed a "Y" -shaped pattern test to evaluate COD and agility in futsal with and without ball using a timing gate system. The COD and agility assessments without the ball requested participants to touch the ball and change direction; with ball, players had to dribble and conduct the ball during the execution of each test. In the COD test, participants had advanced knowledge of the task and knew which cone would light up. In contrast, the agility drill was not planned, and players needed to identify a stimulus and react accordingly. The results demonstrated that both tests were reliable after trials of submaximal intensity, with lower reliability of the non-dominant leg (Sekulic et al., 2019).

In summary, further investigations regarding COD ability are needed in futsal. Strength and conditioning coaches should implement COD training during tactical–technical sessions or develop ACC-DEC capabilities through the use of other training approaches (i.e., resisted sprints, horizontally oriented power exercises, or eccentric training) given the importance of COD maneuvers in futsal.

LIMITATIONS

Some limitations should be addressed when considering the present research. Firstly, the number of studies assessing each variable is quite different, which means that the evidence level is dissimilar among variables. For example, there are more studies describing the match-play demands via time–motion analysis than describing the strength or COD capacities of futsal players. Secondly, the instruments, tests, or data collection procedures differed among studies, which precluded a direct comparison and interpretation of the data in some occasions. Further studies are still necessary to have a clearer picture of the futsal match-play demands, particularly, using new technologies (e.g., GPS or accelerometry-based). In addition, more research into the athletes' physical characteristics and performance outcomes (and how they fluctuate across a competitive season) would bring further understanding on the neuromuscular profile of futsal players.

CONCLUSION

This systematic review provides useful information for strength and conditioning coaches and sport scientists regarding the match demands, anthropometric characteristics, and physical qualities of elite and sub-elite male futsal players. The results indicated that futsal is characterized by intermittent high-intensity activities with a great number of ACC, DEC, and sprints; short recovery times between them; and multiple COD actions during match-play. The abundance of these types of efforts produces important decrements in physiological and neuromuscular responses between the two halves and immediately following match-play. Moreover, biochemical responses appear to be affected up to 24 h after the match. Comparing competition level, differences were observed in match demands, with elite players covering higher distance, performing more high-intensity actions, and presenting lower standing time when compared to sub-elite players. An analysis of the anthropometric characteristics of futsal players showed low percentages of body fat with no differences between on-court players of different positions or level of competition. However, goalkeepers were found to present higher body fat. Regarding the physiological characteristics of futsal players, these display VO_{2max} values of around 62 $ml \cdot kg^{-1} \cdot min^{-1}$. Elite futsal players possess higher VO_{2max}, when compared to their sub-elite counterparts. From the present review, it can be concluded that further investigation on the neuromuscular capabilities (i.e., strength, jumping, and COD) of futsal players is warranted. Still, it appears that elite futsal players present better sprinting abilities when compared to lower-level players but that jumping capacity seems not to differentiate between competition levels. Futsal players aiming to compete at the highest level should focus on developing maximal speed, lower-body power and strength, aerobic capacity, and lean muscle mass.

AUTHOR CONTRIBUTIONS

KS, TF, and PA designed this study. Research literature was conducted by KS and EM-C. KS drafted the manuscript. All authors revised the manuscript and approved the final version to be published.

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SUPPLEMENTARY MATERIAL

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX 2. Study 2: LOAD MONITORING, STRENGTH TRAINING, AND RECOVERY IN FUTSAL: PRACTITIONERS' PERSPECTIVES

Reference:

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Load monitoring, strength training, and recovery in futsal: Practitioners' perspectives

Konstantinos Spyrou[a,b,c], Tomás T. Freitas[a,b,c,d], Rubén Herrero Carrasco[e], Elena Marín-Cascales[c] and Pedro E. Alcaraz[a,b,c]

[a]UCAM Research Center for High Performance Sport, UCAM Universidad Católica de Murcia, Murcia, Spain; [b]Facultad de Deporte, UCAM Universidad Católica de Murcia, Murcia, Spain; [c]Strength and Conditioning Society, Murcia, Spain; [d]NAR – Nucleus of High Performance in Sport, São Paulo, Brazil; [e]Research Group Murcia Soccer Federation, Murcia, Spain

ABSTRACT

This study aimed to describe the current practices in futsal regarding a variety of topics related to performance and injury risk mitigation. Thirty-seven coaches from Spain and Portugal completed a questionnaire consisting of 28 closed questions organized in four categories: a) background information; b) training load (TL) monitoring and assessment of players' physical qualities; c) strength training (ST) practices; and d) recovery (REC) methods. The results showed that coaches varied in experience (1–8 years) and age (from 20 years to >50 years). Overall, 97.3% of the participants declared monitoring TL, with rating of perceived exertion, heart rate monitors, and wearable technology being used by 86.5%, 40.5%, and 37.8%, respectively. Neuromuscular and strength testing are the most common practices to evaluate performance and fatigue during the season. ST is a significant component of futsal, being performed 3 times/week during the pre- and in-season. ST is prescribed via %1RM – XRM (59.5%), velocity-based training (21.7%), repetitions in reserve (18.9%), until failure (10.8%), and circuit training (2.7%). 'Better Monitoring', 'More Individualized', 'Better Facilities', 'More Staff', and 'More Time' were the main aspects to improve ST. Multiple post-match REC strategies are used, with durations ranging from 0–15 to 16–30 min independently of game location.

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Team-sports; five-a-side soccer; performance

Introduction

Futsal is a high-intensity intermittent sport, in which players are exposed to considerable physiological, neuromuscular, and biochemical stress during the game (Spyrou et al. 2020). Match-play data indicate that futsal players cover a total distance of ~4000 m, of which ~675 m are spent running (12–18 km · h^{-1}) and ~130 m sprinting (>18 km · h^{-1}), perform ~70 high-intensity accelerations and decelerations and complete ~170 changes of direction (Ribeiro et al. 2020; Spyrou et al. 2021). In addition, a recent study (Illa et al. 2020) reported that, during a training microcyle, elite futsal players may encounter very high demanding scenarios in terms of locomotor and velocity metrics, reaching values similar to those observed in match-play. As such, not only competition load but also the load players experience in training should be closely monitored.

Strength and conditioning coaches (S&Cc) use training load (TL) as an essential tool to prepare tailor-made training plans and control the volume and intensity of the training sessions (Eckard et al. 2018). The consensus statement of the International Olympic Committee on load in sports and the risk of injury states that a successful TL monitoring system is fundamental to ensure adaptation to stress, maximize physical performance, and possibly minimize the risk of injury (Soligard et al. 2016). The load can be considered as either internal, defined as the physiological or psychological stress imposed on the athlete (i.e., rate of perceived exertion [RPE], heart rate [HR]), or external, the objectively measured work performed [e.g., distance covered, number of accelerations or running speed]) (Halson 2014). Both internal and external load metrics are commonly used for managing the TL in team-sports (Halson 2014; Phibbs et al. 2017). However, when it comes to futsal, it is unclear which methods are the most utilized by current S&Cc from professional teams to monitor the TL and player's physical capacities over the season.

Another important strategy commonly used by S&Cc to reduce injuries in sports (Lauersen et al. 2014, 2018) and enhance physical performance (Rønnestad and Mujika 2014) is strength training (ST), due to its well-documented benefits. For example, Case et al. (2020) found that the maximum pre-season relative back squat strength differed between injured and uninjured males (i.e., football) and female athletes (i.e., softball and volleyball), with significantly lower values found in athletes that sustained an injury during the season. Rønnestad et al. (2011) observed that a weekly ST was enough to maintain strength, sprint, and jump ability during the competitive season, whereas completing only one ST session every second week resulted in a reduction in strength and 40 m sprint performance in professional soccer players. In futsal, Torres-Torrelo et al. (2018) concluded that light load and low volume ST performed twice a week (as a complement to specific futsal training) led to improvements in physical performance, further supporting the importance of training for strength development during the season. Still, to date, little is known concerning ST and its characteristics (i.e., session duration, frequency, and exercise prescription) during normal (e.g., one game/week) and congested (e.g., two or more games/

CONTACT Tomás T. Freitas tfreitas@ucam.edu UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain

week) weeks in futsal. Thus, understanding the ST practices from professional S&Cc may provide important information to other practitioners regarding the training characteristics, methods, and programming strategies currently being used in real-world scenarios.

Futsal competition, as shown in different studies (Spyrou et al. 2020; Nemčić and Calleja-González 2021), produces significant post-match acute and residual physiological, neuromuscular, and biochemical alterations. Neuromuscular capabilities (e.g., peak force) and biochemical variables (e.g., creatine kinase and testosterone/cortisol ratio) may change significantly following match-play (Milioni et al. 2016; Bekris et al. 2022), despite the fact that, in futsal, the number of substitutions is unlimited. Hence, recovery (REC) plays a crucial role when preparing players to cope with the stress they are submitted to during the competitive season. In team-sports, REC methods can be focused on physiological (i.e., active REC, rest, and sleep), physical (i.e., water immersion, contrast therapy, stretching, and massage), psychological, and nutritional (i.e., supplements, nutrition) aspects (Calleja-González et al. 2016). Nevertheless, literature on the REC strategies used in futsal is scarce, especially in terms of the methods employed, its frequency and duration, and the different practices according to game location (i.e., 'home' or 'away') (Nemčić and Calleja-González 2021).

Considering that futsal is an emerging team-sport and that there is still a paucity of research on several important topics (e.g., TL and fatigue monitoring, physical preparation, and REC), characterizing the way S&Cc work in real-world contexts is of interest. This valuable information may allow determining the current strengths, weaknesses, and opportunities for improvement to further develop futsal science and practice. Therefore, the present qualitative study aimed at describing the practices of futsal S&Cc considering 1) the TL monitoring and player's physical capacity evaluation practices across the season; 2) the characteristics and prescription of ST during normal and congested weeks; and 3) the REC strategies and methods following 'home' or 'away' games. There was no leading hypothesis, and the questionnaire was designed to answer the three main research questions declared above.

Material and methods

Study design

An exploratory study was designed to provide descriptive information about TL monitoring, players' performance and fatigue assessment practices, and ST and REC strategies in professional futsal. Data were collected from S&Cc working in Spain and Portugal.

Participants

Thirty-seven male S&Cc (age range: 20 to >50 years; professional experience range: 1 to >8 years), working in the 1st, 2nd, or 2ndB divisions from Spain (n = 24) and Portugal (n = 13), volunteered to take part in the study. According to the inclusion criteria, S&Cc should: a) work in the men's 1st, 2nd, or 2ndB divisions and women's 1st division and b) answer all the questions of the survey successfully. Data were excluded if S&Cc: a) did not work in the above-mentioned divisions or worked exclusively within the club's academy (i.e., youth categories) and b) did not complete the survey or completed it only partially. All participants were informed of the benefits and risks of participating, and informed consent was obtained before undertaking the questionnaire, with the approval of Local Ethics Committee with the registration number CE072008.

Procedures

All S&Cc were contacted electronically to introduce the study and present the informed consent needed to participate in the anonymous online survey. The questionnaire, adapted from previous research (Taylor et al. 2012; Akenhead and Nassis 2016; Starling and Lambert 2018; Griffin et al. 2021) and developed using Google Forms, was sent by email with a web link created with the mentioned platform. The data were collected from February 2021 to April 2021. Responses were screened to determine potential duplicates and questionable answers, such as untruthful, unrealistic, or unfinished responses. The survey consisted of four sections: a) background information (four questions); b) TL monitoring and assessment of players' performance and fatigue (five questions); c) ST practices (thirteen questions); and d) REC methods (six questions). All questions (n = 28) were closed, providing respondents with a predetermined set of answers that included a comment box 'other' in the majority of them. Most questions allowed more than one response because coaches could report using multiple methods. Hence, some questions had more responses than others. Pilot testing of the survey was conducted by all the authors, then by two practitioners (S&Cc) to avoid ambiguity of terms and ensure its validity for use with this population.

Statistical analysis

Statistical analysis was performed using the Jamovi Statistical package (2020; version 1:8). Responses were analyzed using frequency analysis for each question and presented as absolute frequencies and percentages. Mean ± standard deviation (SD) was calculated for a single question: *'The importance of strength in futsal'* as a 1–5 Likert scale (1 = not very important, 5 = extremely important) was used. Thematic analysis was conducted according to Braun and Clarkes' guidelines (Braun and Clarke 2006), previously used in sport science surveys (Crowley et al. 2018; Griffin et al. 2021), with the following six phases: a) familiarization with the data; b) generating initial codes; c) searching for themes; d) reviewing themes; e) defining and naming themes; and f) producing the report.

Results

Coaches' background information

Thirty-seven coaches completed the survey. From the total sample, 76.6% (n = 25) reported working in their respective country's men's 1st Division, 5.4% (n = 2) 2nd Division, 10.8% (n = 4) 2ndB Division, and 16.2% (n = 6) indicated coaching in

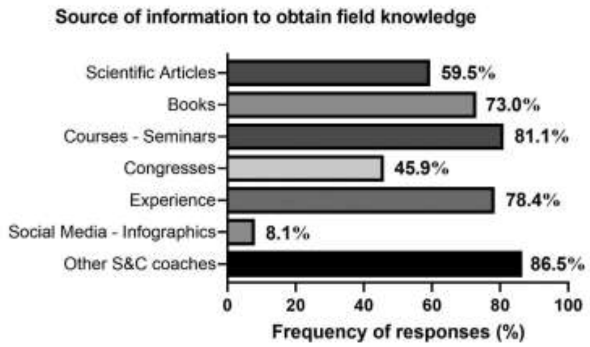

Figure 1. The percentage of the respondents answering the type of resources used to obtain information about their field of knowledge. S&C: strength and conditioning

women's 1st Division. Regarding age, 35.1% of the practitioners were 30–39 years old, 29.7% were 20–29 years old, 24.3% were 40–49, and 10.8% were >50 years old. Considering coaching experience, 43.2% of S&Cc declared working in futsal >8 years, 35.1% between 4 and 7 years, 13.5% between 1 and 3 years, and 8.1% had only 1 year of experience. Finally, when answering the question *'From what type of sources do you obtain information related to your area of expertise?'*, the three most frequent responses were 'Other S&C coach' (86.5%), 'Courses-Seminars' (81.1%), and 'Experience' (78.4%), as shown in Figure 1.

Monitoring practices

Figure 2 outlines the tests and time-periods used for player's performance and fatigue evaluation during the season. S&Cc reported assessing body composition (81.1%), vertical jump ability (72.9%), muscular strength (70.3%),

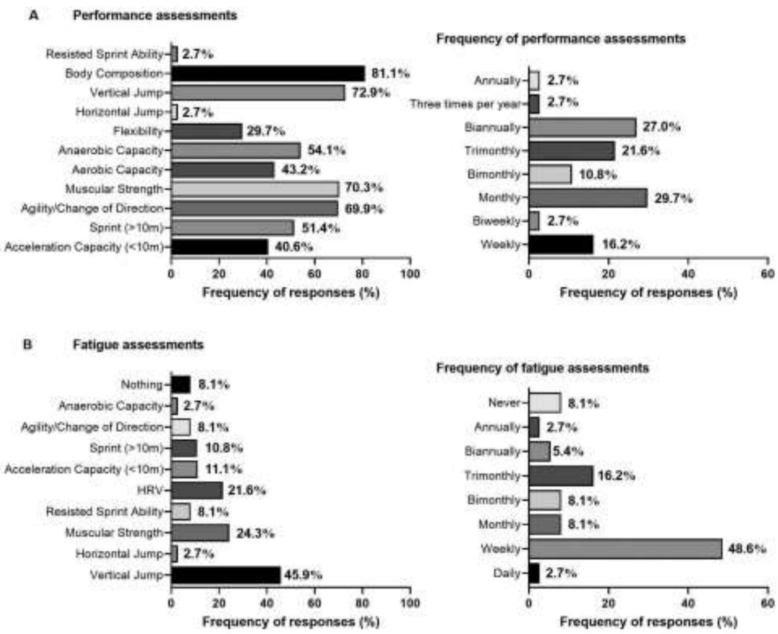

Figure 2. A) The percentage of the respondents answering the tests, and time-interval for player's performance assessment. B) The percentage of the respondents

change of direction-agility (69.9%), anaerobic capacity (54.1%), sprint (>10 m) (51.4%), aerobic capacity (43.2%), acceleration ability (<10 m) (40.6%), and flexibility (27.0%), in testing sessions organized on a monthly (29.7%), biannually (27.0%), trimonthly (21.6%), weekly (16.2%), or bimonthly (10.8%) basis. Regarding player's fatigue, vertical jump ability (45.9%), muscular strength (24.3%), and HR variability (21.6%) were commonly used, being tested weekly (48.6%), trimonthly (16.2%), monthly (8.1%), or bimonthly (8.1%). The most common method for recording TL was RPE (86.5%) followed by external workload monitoring with wearable tracking system (Global Positioning System [GPS]/accelerometer) (37.8%), HR (40.5%), Acute-Chronic Workload ratio (37.8%), and Total Quality Recovery Scale – Wellness (10.8%). Only one (2.7%) S&Cc reported not monitoring TL.

Strength training

Figure 3 depicts the frequency and the duration of ST during pre-season and in-season. Overall, ST was considered as 'extremely important' (4.8 ± 0.4) in futsal. During normal weeks, S&Cc reported completing the first ST on the morning of Match-day (MD) + 2 (43.2%), followed by the afternoon of MD + 1 (16.2%) or morning of MD + 3 (16.2%), and afternoon of MD + 3 (13.5%). Most ST sessions were reported to last 16–30 min (45.9%), followed by 31–45 min (29.7%), 46–60 min (16.2%), 0–15 min (2.7%), 61–75 min (2.7%), and >76 min (2.7%), and focused on full-body training (i.e., upper and lower limbs) (73.0%) and core (67.6%) exercises. During congested periods, 18.9% of the S&Cc reported not prescribing ST. Among those who do, most indicated that ST is performed in the morning of MD + 2 (27.9%), afternoon of MD + 1 (16.2%) or MD + 2 (16.2%), morning of MD + 1 (10.8%), and morning or afternoon of MD + 3 (2.7%). In congested periods, ST sessions last between 16–30 min (45.9%), 0–15 min (24.3%), 31–45 min (18.9%), 46–60 min (8.1%), and 61–75 min (2.7%). The training session is centered on core (62.2%) and full-body (45.9%) exercises.

Concerning ST prescription, the most used method reported was %1RM – XRM (59.5%), followed by velocity-based training (21.7%), repetitions in reserve (18.9%), until failure (10.8%), and circuit training (2.7%). Finally, the main aspects to improve related to ST, as reported by the S&Cc, were as follows: *'Better Monitoring'* (73.5%), *'More Individualized'* (62.2%), *'Better Facilities'* (55.6%), *'More Staff'* (35.1%), and *'More Time'* (10.8%).

Recovery practices

Figure 4 summarizes the REC methods, moment of the application, and duration after 'home' and 'away' competitions. Following 'home' matches, foam roller (78.4%), active REC (76.6%), nutrition (67.7%), water immersion (64.9%), stretching (51.4%), and supplements (51.4%) were the main REC strategies. These were utilized after the match (54.1%), or afternoon MD + 1 (40.5%), and lasted 16–30 min (56.8%), or 31–45 min (29.7%). Regarding 'away' matches, nutrition (67.6%), foam roller (55.9%), supplements (55.9%), and stretching (55.6%) are the main strategies used by S&Cc. The most frequent moments of application were reported to be after the match (43.2%), and

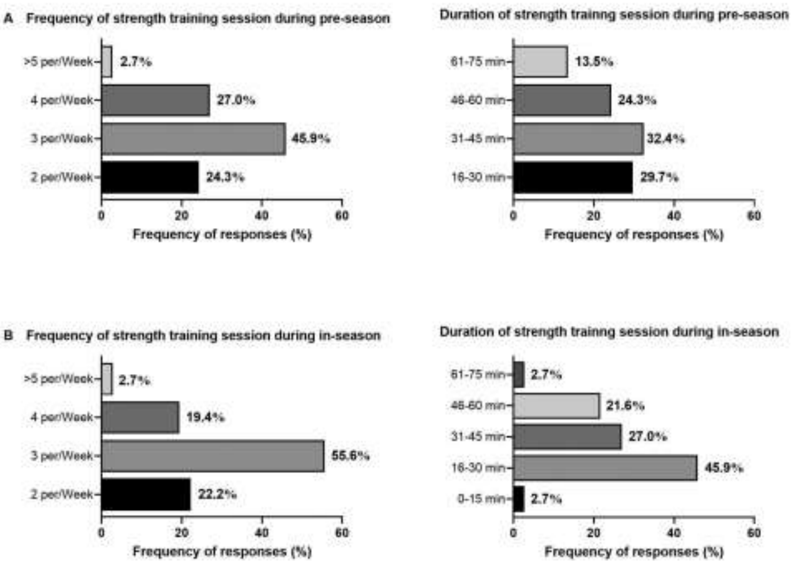

Figure 3. A) The percentage of the respondents answering the frequency and time range of the strength training during the pre-season. B) The percentage of the respondents answering the frequency and time range of the strength training during the in-season. HRV: heart rate variability

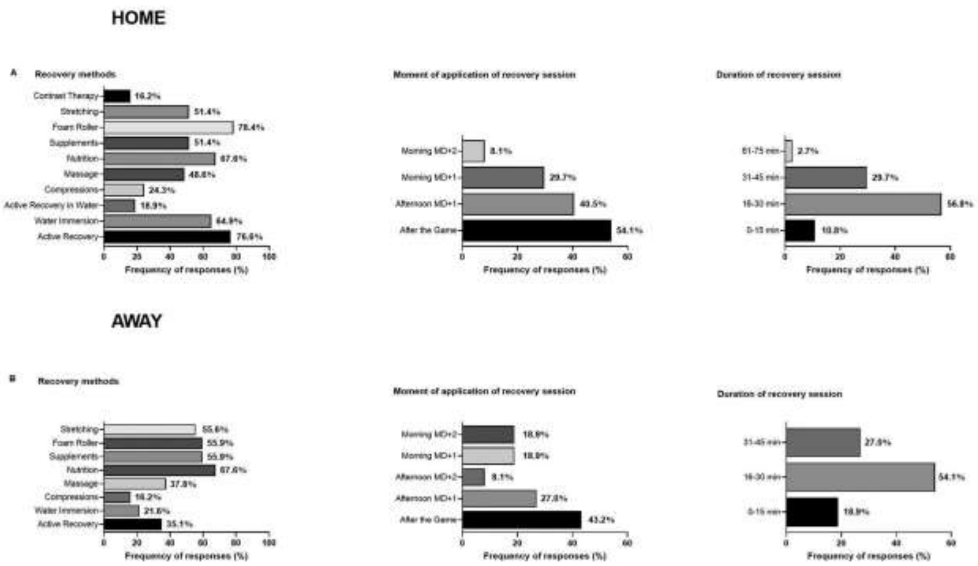

Figure 4. A) The percentage of the respondents answering the methods, moment of the application, and time range of the recovery session after a game at 'home'. B) The percentage of the respondents answering the methods, moment of the application, and time range of the recovery session after a game at 'away'. MD: match-day.

afternoon MD + 1 (27.0%), with durations of 16–30 min (54.1%) and 31–45 min (27.0%).

Discussion

To the best of authors´ knowledge, this is the first study to describe the TL monitoring and physical performance assessment practices and the characteristics of ST and REC strategies in professional futsal. As such, the present findings allow an overview of the current performance and injury mitigation strategies adopted by S&Cc in Spain and Portugal. The main results were as follows: a) virtually all coaches reported monitoring TL, most of them through the use of subjective tools; b) neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and monitor fatigue; c) ST plays a crucial role in physical preparation in futsal and a typical ST session program consists of 3 sessions per week during the pre- and in-season; and d) multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following 'home' and 'away' matches.

Of note, the vast majority (97.3%) of the S&Cc from Portugal and Spain reported monitoring TL (either internal or external) in professional futsal, which is in line with previous studies in high-level football and rugby clubs (Akenhead and Nassis 2016; Griffin et al. 2021). The most common method of recording TL was the RPE with 86.5%, followed by HR and GPS/accelerometry systems that were used by 40.5% and 37.8%, respectively. Interestingly, these results contrast with those obtained in professional soccer, where the majority of coaches reported collecting HR data and GPS/accelerometry and only a few utilized RPE and other subjective variables (Akenhead and Nassis 2016; Loturco et al. 2022). A possible explanation may be related to the fact that the use of GPS technology is inoperable in indoor sports (Torres-Ronda et al. 2022), and that local positioning systems must be installed in the team's facilities, which limits its application in, for example, 'away' games. As a consequence, the use of wearable tracking systems is somehow limited in futsal (i.e., it is not possible to obtain distance or velocity metrics), as only accelerometry data can be analyzed (Torres-Ronda et al. 2022). Another potential factor explaining the differences between futsal and soccer with respect to TL monitoring is related to the economic disparities between both sports since HR and GPS/accelerometry wearable technology are expensive (hence, more difficult to implement in futsal) and RPE is a 'low cost' solution. In support of this notion, a previous study (Griffin et al. 2021) in amateur rugby union found that the most common method to record TL was, indeed, RPE. From a practical perspective, the present results reinforce that, even in the absence of abundant economic resources, monitoring TL during the season is possible (and recommended), as shown by the high percentage of S&Cc that reported using subjective variables (e.g., RPE).

Considering player's physical capacities testing across the season, S&Cc generally evaluate body composition (81.1%), vertical jump ability (72.9%), muscular strength (70.3%), change of direction-agility (69.9%), followed by anaerobic capacity (54.1%) sprint (>10 m) (51.4%), aerobic capacity (43.2%), and acceleration ability (<10 m) (40.6%) (Figure 2). These tests are usually conducted monthly (29.7%), biannually (27.0%), tri-monthly (21.6%), weekly (16.2%), and bimonthly (10.8%). Regarding player's fatigue, S&Cc reported conducting assessments mostly every week (Figure 2) with vertical jump height, muscular strength, and HR variability being the variables most commonly tested. Remarkably, it seems that neuromuscular and strength capacity evaluations are used to evaluate both performance and fatigue during the season with different frequency between practitioners in futsal. These results are in line with previous research (Taylor et al. 2012; McGuigan et al. 2021) that have demonstrated that jump tests, strength measurements, and sport-specific assessment protocols are commonly used in other team-sports, implemented on a weekly or monthly basis. Noteworthy, other studies (Akenhead and Nassis 2016; Starling and Lambert 2018) presented that S&Cc implement questionnaires or GPS/accelerometry systems to manage performance and fatigue status, which contrasts with the present investigation where these methods were reported to be used to control TL and not evaluate player's physical capacities. In applied settings, and according to the current practices in professional futsal, it appears that S&Cc consider that evaluating players' physical capacities during the season is valuable and allows for adjustments in the training plan to be made accordingly.

When inquired about ST, all practitioners reported it to be a significant and highly important training component in futsal (i.e., 4.8 ± 0.4 out of 5). Previous studies have confirmed the positive effects of ST on physical capacities in futsal (Torres-Torrelo et al. 2017, 2018; Marques et al. 2019). Specifically, Marques et al. (2019) found significant improvements in physical performance (i.e., countermovement jump height, sprint time, *T*-Test time, kicking ball speed, and maximum strength in leg-press) following two weekly ST sessions complementing specific futsal training. In the present study, S&Cc reported prescribing ST mainly 3 times/week (55.6%), with sessions lasting 31–45 min (32.4%), 16–30 min (29.7%), or 46–60 (24.3%) in the pre-season. During in-season, practitioners declared performing 3 weekly ST sessions (45.9%), but with shorter durations (16–30 min, 45.9%; 31–45 min, 27.0%; and 46–60, 21.6%) (Figure 3), most likely due to the limited time to dedicate to the development of physical qualities during the training week. A novel aspect within this investigation was related to how S&Cc vary their ST practices depending on the competitive calendar (i.e., normal vs. congested weeks). Interestingly, the first ST during a normal week is performed mostly on the morning of MD + 2 (43.3%) and comprises both lower and upper body lifts (73%) and core (67.6%) exercises. During congested periods, short (i.e., 16–30 min, 45.9% or 0–15 min, 24.3%) ST sessions focused on the core musculature (62.2%) and (to a lesser extent when compared to normal weeks) lower and upper limb exercises (45.9%) are executed in the morning of MD + 2 (27.9%). However, these results should be interpreted cautiously as they are mainly anecdotal evidence, and more research is needed on the effects of ST on players´ performance and REC profile during normal and congested weeks in futsal.

Considering the REC methods in futsal, current evidence-based knowledge is poor (Nemčić and Calleja-González 2021) as only few studies have investigated this topic (Tessitore et al. 2008; Wilke et al. 2019; Nunes et al. 2020; Rahimi et al. 2020). Nevertheless, and although their results should be interpreted with caution due to some of the parameters used to evaluate REC, Rahimi et al. (2020) found that utilizing foam rollers resulted in superior REC effects as assessed by subjective variables, and physical performance when compared to passive REC. Furthermore, Tessitore et al. (2008) analyzed the effects of immediate postgame REC interventions (i.e., seated rest, supine electrostimulation, low-intensity land exercises, and water exercises), and found no significant differences among REC interventions for anaerobic indicators, hormonal responses, muscle pain, and players' perceptions of REC (i.e., questionnaires). Regarding the results obtained herein, it seems that S&Cc adjust REC approaches depending on the game location (i.e., 'home' versus 'away'). Precisely, active REC, water immersion, and massage therapy appear to be more utilized following 'home' games when compared to 'away' (76.6% vs 35.1%; 64.9% vs 21.6%; 48.6% vs 37.8%, respectively). However, foam roller, stretching, nutritional, and supplementation strategies are independent of the game location as the percentages of each do not differ greatly. Of note, REC sessions are mainly taking place after the game (43.2% and 54.1% following 'home' and 'away' games, respectively) or on the afternoon of MD + 1 ('home': 40.5%; 'away': 27%) and last 15–30 min (Figure 4). Nevertheless, more research on the effects of different REC methods on futsal players and their individual response is warranted.

Whilst this is the first study to investigate the coaches' methods for monitoring TL, player's physical capacities, and the programming of ST and REC sessions, it is not without limitations. It is important to acknowledge that the results are based solely on the beliefs, experiences, or training philosophy of S&Cc and that different staff members (e.g., physiotherapists, nutritionists, etc.), who are directly involved in injury risk mitigation and REC strategies were not included. Furthermore, players did not participate in the survey, which limits access to important information such as whether they use further assistance on REC or physical preparation in their own time, outside club's facilities. These findings should not be generalized, as the data were collected only from practitioners working in Spain and Portugal and must be applied with caution due to the plethora of contextual factors (i.e., international and national tournaments, club's philosophy, etc.), team's resources, and players' individuality (e.g., sex or training background) that may have influenced the results. Still, describing coaches' perceptions and practices about the topics addressed herein is certainly vital for helping the futsal community understand its strengths, weaknesses, and opportunities for improvement in terms of TL, fatigue monitoring, physical preparation, and REC.

This study provides a comprehensive insight into the TL monitoring, players' physical capacity assessment, and the characteristics of ST and REC practices in futsal in Spain and Portugal. All coaches reported monitoring TL, most of them through the use of subjective tools (e.g., RPE). As such, following the practices already implemented in other sports, futsal teams should provide more financial and technical support, to allow hiring more staff members and acquiring, for example, HR or GPS/accelerometry systems, in order to optimize training monitoring and prescription. Neuromuscular and strength measurements are among the strategies that practitioners utilize to evaluate performance and fatigue. From an applied perspective, S&Cc should integrate tests in the training sessions to frequently obtain information on their athletes' performance/fatigue status. ST plays a crucial role in physical preparation in futsal. A typical ST session program consists of 3 sessions per week during the pre- and in-season, focused on upper and lower limb exercises and core strengthening. A possible solution employed by coaches to ensure that this training frequency is met is to reduce the duration of the ST sessions during the competitive phase of the season. Lastly, multiple REC strategies (i.e., foam roller, stretching, nutritional, and supplementation strategies) are used following 'home' and 'away' matches. In applied settings, S&Cc are advised to implement the above-mentioned REC strategies independently of the game location.

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ORCID

Konstantinos Spyrou http://orcid.org/0000-0002-5762-4653
Tomás T. Freitas http://orcid.org/0000-0001-8571-3189
Elena Marín-Cascales http://orcid.org/0000-0002-7327-0963
Pedro E. Alcaraz http://orcid.org/0000-0002-9792-6656

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APPENDIX 3. Study 3: EXTERNAL MATCH LOAD AND THE INFLUENCE OF CONTEXTUAL FACTORS IN ELITE FUTSAL

Reference:

Spyrou, K., Freitas, T. T., Marín-Cascales, E., Herrero-Carrasco, R., & Alcaraz, P. E. (2021). External match load and the influence of contextual factors in elite futsal. Biology of Sport, 39(2), 349-354.

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External match load and the influence of contextual factors in elite futsal

AUTHORS: Konstantinos Spyrou[1,2], Tomás T. Freitas[1,2,3,4], Elena Marín-Cascales[4], Rubén Herrero-Carrasco[5], Pedro E. Alcaraz[1,2,4]

[1] UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain
[2] Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain
[3] NAR – Nucleus of High Performance in Sport, São Paulo, Brazil
[4] Strength and Conditioning Society, Rome, Italy
[5] Research Group Murcia Soccer Federation, Murcia, Spain

Corresponding author:
Tomás T. Freitas
UCAM Research Center for High Performance Sport, Catholic University of Murcia, Spain
E-mail: tfreitas@ucam.edu

ORCID:
Tomás T. Freitas
0000-0001-8571-3189

Konstantinos Spyrou
0000-0002-5762-4653

Pedro E. Alcaraz
0000-0002-9792-6656

Elena Marín-Cascales
0000-0002-7327-0963

ABSTRACT: Quantifying external load during futsal competition can provide objective data for the management of the athlete's performance and late-stage rehabilitation. This study aimed to report the match external load collected via wearable technology according to time periods (i.e., halves) and contextual factors (i.e., team's ranking, match result, and location) in elite futsal. Nine professional male players used a GPS-accelerometer unit during all games of the 2019–2020 season. Player load (PL), PL·min^{-1}, high-intensity acceleration (ACC_{HI}), deceleration (DEC_{HI}), explosive movements (EXPL-MOV), and change of direction (COD_{HI}) data were collected. On average, players displayed values of: total PL 3868 ± 594 a.u; PL·min^{-1}: 10.8 ± 0.8 a.u; number of ACC_{HI}: 73.3 ± 13.8, DEC_{HI}: 68.6 ± 18.8, EXPL-MOV: 1165 ± 188 and COD_{HI}: 173 ± 29.1. A moderate and significant decrease was found in the 2nd half for total PL (p = 0.03; ES = 0.52), PL·min^{-1} (p = 0.001; ES = 1.16), DEC_{HI} (p = 0.001; ES = 0.83), and EXPL-MOV (p = 0.017; ES = 0.58) compared to the 1st half. Small and non-significant differences were found between contextual factors. In summary, this study indicates that futsal players are exposed to high-intensity mechanical external loads, and perform a great number of ACC_{HI}, DEC_{HI}, EXPL-MOV and COD_{HI}, without being influenced by the team ranking, result and match location. Coaches and sports scientists are advised to implement speed-power, DEC, and COD activities in the training sessions, and may use these reference values to design specific training and return-to-play plans.

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INTRODUCTION

Futsal is an indoor sport characterized as a high-intensity intermittent modality with high physical, technical, and tactical demands [1, 2]. Due to its increased popularity, better understanding of the activity profile of futsal match play has been a main interest of practitioners and researchers. In this regard, several studies have investigated the match demands in futsal using different approaches, such as time-motion analysis [1, 3–5], monitoring physiological parameters (e.g. heart rate and oxygen consumption) [6, 7] and, more recently, wearable technology tracking (global positioning system [GPS]/accelerometer) [8, 9].

Through time-motion analysis, it was observed that, during a match, players execute ~30 sprints, comprising sequences of 2, 3, and 4 consecutive sprints, separated by rest intervals of 30, 45, or 60 s [4]. Match external load refers to the physical demands (i.e., accelerations [ACC] and decelerations [DEC], changes of direction [COD] and jumps) derived from position data or inertial measurement units [10]. Recently, Ribeiro et al. [8], using GPS technology, reported that futsal players covered 3750 ± 1123 m, from which 135 ± 54 m were completed sprinting (> 18 km·h^{-1}). Moreover, players executed a great number of ACC (5 ± 2 n·min^{-1}), and DEC (5 ± 2 n·min^{-1}) relative to "court time" [8]. These data confirm the importance of high-intensity efforts during futsal match-play. Still, when it comes to a precise quantification of actions such as ACC, DEC, and COD, evidence is still scarce. More research is warranted since studies investigating these variables using wearable technology analysed only a small number of matches [8, 9].

When examining a futsal game's demands more thoroughly, different investigations [1, 3, 6, 7] have confirmed that the match activity tends to decrease from the 1st to the 2nd half. For example, Milioni et al. [7] found that total distance covered, distance per min, maximal isometric force and voluntary activation were inferior in the 2nd half compared to the 1st in a simulated match. Bueno et al. [3] reported an increase of the percentage of standing and the distance covered at walking velocity in the 2nd half compared to the 1st;

in contrast, the percentage of medium- and high-intensity activity decreased in the 2nd half of an official game. Interestingly, data collected using GPS revealed no meaningful differences in metabolic, kinematics, and mechanical activity between halves [8]. Due to these inconsistencies, further research is needed to better clarify the demands of each half.

Considering contextual factors, studies from different sports [11–16] suggest that opponent's ranking and match location or result may affect game demands. For instance, Goodale et al. [14] found that female rugby players covered higher total, medium- and high-intensity running distances during losses and against top-ranking opponents compared to wins and bottom-ranked opponents. Moreover, Vescovi et al. [16], investigating the match demands and the impact of contextual factors in professional female soccer, detected no differences between home and away competition, but that the relative distance covered was greater during losses. Notably, when it comes to futsal, the influence of contextual factors has been addressed mainly from a technical-tactical perspective [17], but the literature is scarce regarding external match load variations, particularly using wearable technology-derived variables. This information may be extremely helpful for coaches as determining match demands based solely on video-analysis tools may be considerably time-consuming and limit the proper quantification of non-locomotor activities influencing sports performance (e.g., impacts or collisions) [18]. As such, a better understanding of match external loads monitored via wearable technology may help coaches and sports scientists to prescribe training sessions more related to the actual efforts and demands of competition, thus enhancing performance and potentially reducing the risk of injury.

Based on the above considerations, the main purposes of this study were: 1) to quantify the match external load and movement demands during competitive professional futsal matches while identifying differences between time periods (i.e., 1st and 2nd halves) using accelerometer-based technology; and 2) to investigate whether contextual factors (i.e., opposing team's ranking, match outcome, and location) affect external load variables during the match. It was hypothesized that there would be a significant decrease in the external load parameters in the 2nd half with respect to the 1st half and that external mechanical loads would be higher against top-ranked teams, in "wins" and during "home" games.

MATERIALS AND METHODS

Study Design

A retrospective, observational, cohort study design was used. The match activity profile of elite male futsal players was collected using wearable technology (i.e., accelerometers [Catapult Innovation; Melbourne, Australia]) throughout the season 2019–2020 (20 games). Consistent with the *Liga Nacional de Fútbol Sala* (LNFS; 1st Division of Spain) rules, games lasted 40 min and consisted of two 20-min halves separated by a 10-min break. Only 10 of the team's 15 players were monitored, because of the GPS availability. The study procedures did not influence or alter the match in any way. To compare teams' ranking, the following criteria were determined: "high": the top five teams in the league (excluding the monitored team) (n = 6 matches); "medium": the following five teams (n = 8 matches); "low": the bottom five teams of the league (n = 6 matches). Match outcome was classified as a "win" (n = 13 matches), "loss" (n = 5 matches) or "draw" (n = 2 matches). Due to the small number of "draws", this condition was excluded from the present study. Match location was referred to as "home" (n = 12) or "away" (n = 8).

Participants

Ten elite male futsal players (age: 26.7 ± 3.1 years old, body mass: 74.7 ± 5.9 kg, height: 1.78 ± 0.06 m, body fat: 8.8 ± 1.5%), members of a team competing in the LNFS and finalists of the UEFA Futsal Champions League, were monitored for this study. Only data from on-court players selected by the coaching staff in the pre-season to wear the technology and who participated in at least 75% of the games throughout the season were considered for analysis. One of the players did not complete > 75% of games due to injury and was excluded from the study's sample. As a consequence, 9 players (back: n = 3; wing: n = 4; pivot: n = 2) finally participated in the investigation. By signing a professional contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

Procedures

Instrumentation: The activity profile data were collected via a portable GPS unit, Catapult Sport Optimeye S5 (Catapult Innovation; Melbourne, Australia), comprising a tri-axial accelerometer, gyroscope, and magnetometer, which provide data for inertial movement analysis at a sampling rate of 100 Hz. Previous research has reported this technology to be valid and reliable [19]. The devices were fitted to the upper back of each player using a specific vest under the athlete's jersey. To avoid potential inter-unit error, each player wore his own device, which was the same throughout the season [20]. To represent the match-play cumulative load, data collection was initiated when players were in the locker room after the warm-up period, 10 min before starting the match, and concluded before the postgame cool-down. All data were analysed by Catapult Sport Openfield software (Catapult Innovation; Melbourne, Australia), which applies specific algorithms to transform the input of raw inertial data during athlete movement into meaningful and standardized output variables used to quantify the movement experience.

Activity Profile Data: Variables of interest in this study included average and total player load (PL), PL per minute (PL·min^{-1}), high-intensity ACC (ACC_{HI}), high-intensity DEC (DEC_{HI}), explosive movements (EXPL-MOV), and high-intensity COD (COD_{HI}). PL consists of the sum of the accelerations across all axes of the internal tri-axial accelerometer during movement (100 Hz), applying the established formula [21] and expressed as an arbitrary unit (a.u). PL·min^{-1} divides the accumulated PL by time, providing an intensity index and expressed as an a.u [22]. ACC_{HI} refers to the total inertial movements registered in a forward acceleration vector within the high band (> 3.5 m·s^{-2}) and DEC_{HI} corresponds to the total inertial movements in a deceleration vector within the high band (< -3.5 m·s^{-2}). COD_{HI} represents total inertial movements registered in a rightward/leftward lateral vector within the high band (> 3.5 m·s^{-2}). Regarding the number (i.e., count) of ACC_{HI}, DEC_{HI} and COD_{HI}, only high-intensity inertial movements were considered in the present research. EXPL-MOV encompass the total inertial movements irrespective of the direction (i.e., ACC, DEC and COD; jumps not included) within the medium and high bands (> 2.5 m·s^{-2}). Previous studies [23, 24] have already investigated and confirmed the validity and reliability of the aforementioned variables (i.e. ACC_{HI}, DEC_{HI}, EXPL-MOV, and COD_{HI}).

Statistical Analysis

Statistical analysis was performed in the Jamovi statistical package (2020; Version 1.2). Data are presented as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was used to determine the differences among opposing teams' levels. Post-hoc pairwise comparisons were performed to identify significant main effects between high, medium, and low ranking teams. To detect differences between game periods (i.e., 1st and 2nd halves) the paired sample t-test was applied. To analyse the contextual factors (i.e., home-away, and win-loss games), independent samples t-tests were performed. Cohen's effect sizes (ES) were computed to determine the magnitude of every paired comparison and classified as: trivial (< 0.2), small (> 0.2–0.6), moderate (> 0.6–1.2), large (> 1.2–2.0), and very large (> 2.0–4.0) [25]. The significance level was set as $p \le 0.05$.

RESULTS

Table 1 depicts the external match demands considering the full-game data as well as the 1st and 2nd halves separately (i.e., average values from all games). A significant and small-moderate decrease in total PL and PL·min^{-1} was observed in the 2nd half. Moreover, the number of DEC_{HI} and EXPL-MOV was significantly lower during the 2nd half, with small to moderate effect sizes. Small non-significant differences were obtained for ACC_{HI}, and COD_{HI}.

Tables 2 and 3 display the external load variables according to the contextual factors. No significant differences were attained in external match load metrics regarding the opposing team's level, the match outcome and the match location.

TABLE 1. Match-play demands and comparison between the 1st and 2nd halves.

Variables		Full Game	1st Half	2nd Half	*p* value	ES
Total PL	a.u	3868 ± 594	1990 ± 299	1868 ± 344*	0.030	0.52
PL·min^{-1}	a.u	10.8 ± 0.8	11.2 ± 0.9	10.4 ± 1.0*	0.001	1.16
ACC_{HI}	n°	73.3 ± 13.8	36 ± 7.3	37.3 ± 9.9	0.593	0.12
DEC_{HI}	n°	68.6 ± 18.8	38 ± 9.4	30.6 ± 11.3*	0.001	0.83
EXPL-MOV	n°	1165 ± 188	611 ± 97	559 ± 108*	0.017	0.58
COD_{HI}	n°	173 ± 29.1	89.5 ± 19.6	85 ± 16.4	0.410	0.18

Values expressed as mean ± SD. *$p \le 0.05$; significant first and second half difference by a Paired Sample T-Test. ACC_{HI}: high-intensity acceleration; a.u: arbitrary units; COD_{HI}: high-intensity change of direction; DEC_{HI}: high-intensity deceleration; ES: effective size; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

TABLE 2. Futsal match-play demands according to the opposing team's ranking position.

Variables		High (n = 6)	Medium (n = 8)	Low (n = 6)	*p* value
Total PL	a.u	4021 ± 653	3802 ± 703	3804 ± 522	0.795
PL·min^{-1}	a.u	10.3 ± 0.9	11.0 ± 0.9	11.0 ± 0.6	0.328
ACC_{HI}	n°	81 ± 5.5	71.7 ± 14.1	68.8 ± 16.6	0.625
DEC_{HI}	n°	73 ± 18.9	69.7 ± 19.5	64.5 ± 19.9	0.732
EXPL-MOV	n°	1217 ± 163	1171 ± 233	1122 ± 182	0.131
COD_{HI}	n°	185 ± 24.1	166 ± 39.5	170 ± 24.5	0.477

Values expressed as mean ± SD. ACC_{HI}: acceleration; a.u: arbitrary units; COD_{HI}: change of direction; DEC_{HI}: deceleration; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

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PL·min^{-1}	a.u	10.8 ± 0.8	11.2 ± 0.9	10.4 ± 1.0*	0.001	1.16
ACC_{HI}	n°	73.3 ± 13.8	36 ± 7.3	37.3 ± 9.9	0.593	0.12
DEC_{HI}	n°	68.6 ± 18.8	38 ± 9.4	30.6 ± 11.3*	0.001	0.83
EXPL-MOV	n°	1165 ± 188	611 ± 97	559 ± 108*	0.017	0.58
COD_{HI}	n°	173 ± 29.1	89.5 ± 19.6	85 ± 16.4	0.410	0.18

Values expressed as mean ± SD. *$p \leq 0.05$; significant first and second half difference by a Paired Sample T-Test. ACC_{HI}: high-intensity acceleration; a.u: arbitrary units; COD_{HI}: high-intensity change of direction; DEC_{HI}: high-intensity deceleration; ES: effective size; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

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Variables		High (n = 6)	Medium (n = 8)	Low (n = 6)	*p* value
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Values expressed as mean ± SD. ACC_{HI}: acceleration; a.u: arbitrary units; COD_{HI}: change of direction; DEC_{HI}: deceleration; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

TABLE 3. Match-play external load according to match result and location.

Variables		Match Result		p value	ES	Match Location		p value	ES
		Win (n = 13)	Loss (n = 5)			Home (n = 12)	Away (n = 8)		
Total PL	a.u	3846 ± 623	3990 ± 689	0.675	0.22	3757 ± 646	4036 ± 498	0.315	0.47
PL·min^{-1}	a.u	11.0 ± 0.7	10.2 ± 1.0	0.082	0.97	11.0 ± 0.5	10.5 ± 1.0	0.174	0.64
ACC_{HI}	n°	72.1 ± 16	79.4 ± 4.3	0.337	0.52	72.6 ± 15.9	74.4 ± 10.7	0.784	0.12
DEC_{HI}	n°	67.2 ± 20.8	70.4 ± 19	0.766	0.15	67.4 ± 20.7	70.4 ± 16.7	0.741	0.15
EXPL-MOV	n°	1157 ± 203	1210 ± 179	0.621	0.26	1134 ± 206	1212 ± 157	0.376	0.41
COD_{HI}	n°	171 ± 31.1	182 ± 26.2	0.491	0.37	169 ± 33.6	180 ± 21	0.405	0.38

Values expressed as mean ± SD. ACC_{HI}: high-intensity acceleration; a.u: arbitrary units; COD_{HI}: high-intensity change of direction; DEC_{HI}: high-intensity deceleration; ES: effect size; EXPL-MOV: explosive movements; n°: number; PL: player load; PL·min^{-1}: player load per minute; SD: standard deviation.

DISCUSSION

The present study investigated the external load demands of elite male futsal match-play by describing six variables (i.e., PL, PL·min^{-1}, number of ACC_{HI}, DEC_{HI}, EXPL-MOV and COD_{HI}) collected via wearable technology. The current research is of interest for practitioners as it provides descriptive data pertaining to a top-3 futsal team competing in Spain's 1st Division that was monitored throughout the entire season. Remarkably, for the first time, we identified, by accelerometry-based data, that a significant decrease in PL, PL·min^{-1}, DEC_{HI}, and EXPL-MOV occurs in the 2nd half compared to the 1st. In contrast, other variables such as ACC_{HI} and COD_{HI} appear not to decline significantly as the match progresses. Finally, another key finding was that contextual factors (i.e., opponent team's level, match outcome, and match location) seem not to influence the external match load metrics.

Regarding match demands, the present results reinforce previously published research [1, 3, 4, 6, 8, 26] and confirm, through accelerometry data, that futsal is, indeed, a high-intensity intermittent modality in which players perform multiple ACC_{HI}, DEC_{HI}, and COD_{HI} actions [2]. Specifically, players were found to perform, on average, around 1165 ± 188 moderate-to-high-intensity explosive actions (> 2.5 m·s^{-2}) in all planes of movement during a single match. These results are in line with a previous study [8] that investigated the external match demands by GPS and reported that futsal players may perform around 80 ACC and DEC actions during match-play. From a practical standpoint, identifying these variables is extremely useful for strength and conditioning coaches to prepare more specific training plans according to the demands that players are expected to encounter during competition, and to plan safer return-to-play protocols.

Of note, when analysing game periods (i.e., halves), players displayed higher total PL, PL·min^{-1}, and DEC_{HI} and EXPL-MOV in the 1st half than in the 2nd. Similar results were obtained by other authors [1, 3, 6, 7] using time-motion analysis and indicating that the percentage of distance covered at medium and high-velocity, and sprinting was greater during the 1st half. However, reports of no significant differences between the two halves can also be found in the literature [4, 8]. For example, Ribeiro et al. [8] found that kinematic (i.e., distance covered per min, sprints), mechanical (i.e., ACC, DEC), and metabolic variables (i.e., metabolic power per min) were not affected by time periods. These contradictory results could be explained by different factors related to futsal's characteristics (e.g., unlimited number of substitutions), or tactical decisions (e.g. "fly goalkeeper"). Further research on the influence of tactical behaviours in external match load activities (i.e., complementing the recent work by Rico-González et al., [17]) is warranted. Based on the above, strength and conditioning coaches should prepare the players to be able to complete and tolerate high-intensity activities until the end of the game.

Regarding the influence of the opposing team's ranking on the league, no significant differences were observed for any external load variable, which indicates that similar physical demands are placed on players when playing against the top or bottom competitors, in order to achieve a positive result. Along the same lines, related studies [11, 15] on other team sports have displayed similar physical match demands against low-, medium- and, high-level opponents. However, Goodale et al. [14] found that total distance covered and activities at moderate and high speeds were higher when playing against the top 4 opponents compared to the bottom 4. From an applied perspective, these findings suggest that players are exposed to high mechanical loads irrespective of the level of the opposing team; hence, from a physical preparation standpoint, training loads should not be greatly altered the week prior to playing, for example, a bottom-ranked team.

Considering match result (i.e., win-loss), no significant differences were found in external match load. The present data do not seem to support a previous study [13] that found that the number of jumps, ACC_{HI}, DEC_{HI}, and COD were higher during losses compared to wins in basketball. Additionally, Vescovi et al. [16] observed that relative sprint distance was greater during losses than draws in professional women soccer players. It is probable that tactical aspects could explain these disparities as, in futsal, it is common for teams to follow the same tactical move when losing the match: playing with a "fly goalkeeper" which "slows down" the game. In applied settings, coaches and sports practitioners should consider that players are exposed to similarly high match demands after losing (in comparison with wins or draws), and that appropriate training load management is necessary. Therefore, the tendency to train "harder" after losses should be avoided as it could lead to detrimental effects on players' physical performance.

The external match load and activity profile were similar regardless of the game location (i.e., home versus away). Given that during the season travel time does not usually exceed ~3 hours by flight or bus in Spain, travel fatigue would most likely not affect players' performance. Moreover, most of the players had experience playing in national and international leagues (i.e., LNFS, Champion League), which ensures a high level of familiarity with travelling. Previous research [12, 16] from other team sports supports the present results. Professional female soccer players were found to experience no differences in physical demands irrespective of match location [16]. Conversely, related studies [27, 28] have reported a significant decline in performance when playing "away" compared to "home". Still, caution is necessary when comparing results from different studies. There are important factors that could influence the outcomes such as sport characteristics (i.e., futsal, soccer, and rugby), travel time or even time-zone changing since long-haul, and transmeridian travelling has been suggested to affect players' performance [29, 30].

This study is limited by its small sample size. Nevertheless, it is worth noting that the present research presents accelerometry-based match data from a total of 20 games from a professional, top-3 LNFS team and finalist of the UEFA Champions League. Previous studies using similar technology analysed six [8] and three [9] games and both agreed that studies comprising a greater number of matches are necessary. A second limitation is that the match external load was monitored only for on-court players, and no goalkeepers' demands during the match-play were considered. Lastly, it is limited by the difference between the total number of matches classified as "wins" (n = 12) and "losses" (n = 5).

From an applied perspective, based on the findings herein, intermittent game-based drills that require multiple high-intensity efforts (e.g., short sprints in multiple directions or DEC) and speed-power exercises should be prioritized in training. These activities will seemingly prepare players to perform and tolerate activities similar to the ones they may encounter during match-play. Additionally, and in contrast with the initial hypothesis, contextual factors (i.e., team ranking, match result, and location) appear not to affect the external match load in futsal; thus, coaches should not substantially alter their weekly training plan (from a physical preparation perspective) whether the team plays at home or away, or against a top- or bottom-ranked opponent. Lastly, coaches and sports scientists can utilize these results as a reference to design specific training and return-to-play plans.

CONCLUSIONS

Through the analysis of accelerometry-based data, this study indicates that futsal players are exposed to high mechanical external loads, and perform a great number of ACC_{HI}, DEC_{HI}, COD_{HI}, and EXPL-MOV during a match. Additionally, higher total PL, PL·min^{-1}, DEC_{HI}, and EXPL-MOV are obtained in the 1st half than the 2nd. Contextual factors (i.e. match result, team's ranking and match location) do not seem to affect any of the external variables studied. Coaches and sport scientists should consider the present findings when planning specific training sessions and return-to-play approaches from an injury perspective.

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Conflict of interest declaration

The authors report no conflict of interest.

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APPENDIX 4. Study 4: DIFFERENCES BETWEEN OFFICIAL AND NON-OFFICIAL MATCHES IN WORST-CASE SCENARIOS IN ELITE FUTSAL PLAYERS

Reference:

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Differences between official and non-official matches in worst-case scenarios in elite futsal players

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Konstantinos Spyrou[1,2,4 ABCDE], Tomás T. Freitas[1,2,3,4 ACE], Elena Marín-Cascales[4 BDE], Rubén Herrero-Carrasco[5 BDE], Pedro E. Alcaraz[1,4 AE]

[1] UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain

[2] Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain

[3] NAR – Nucleus of High Performance in Sport, São Paulo, Brazil

[4] Strength and Conditioning Society, Rome, Italy

[5] Research Group Murcia Soccer Federation, Murcia, Spain

abstract

Background: This study aimed to compare the worst-case scenarios (WCS) between official (OFF) and non-official (Non-OFF) matches, in different time-periods in an elite futsal team.

Material and methods: Twenty-six games were divided into OFF (n = 13) and Non-OFF (n = 13). The WCS were calculated using: two methods, rolling averages (ROLL) and fixed-periods (FIX); four-length epochs (30-s, 1-, 3-, and 5-min); and player load per minute (PL·min^{-1}).

Results: Considering ROLL, significant and small differences were found in PL·min-1, with higher intensity in 30-s ($p = 0.001$; ES = -0.53) and 1-min ($p = 0.001$; ES = -0.47) in OFF when compared to Non-OFF, but non-significant and small to trivial changes in 3-min ($p = 0.060$; ES = -0.23) and 5-min ($p = 0.605$; ES = -0.06) were observed. Regarding FIX, significant and small changes were obtained, with higher intensity in OFF in all time-periods when compared to Non-OFF. Significant differences were found between the two methods (ROLL vs FIX) in 30-s, 1- and 3-min, but not in 5-min. Significant differences, with lower PL·min^{-1}, were observed with increasing time-windows from both methods ($p = 0.001$).

Conclusions: In summary, OFF matches present higher WCS than Non-OFF ones when considering short time-periods, and the FIX method could underestimate the "actual intensity" of the match compared to ROLL.

Key words: five-a-side soccer; most demanding passages; external load; performance.

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Corresponding author: Konstantinos Spyrou; UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain, Campus de los Jerónimos, 30107, Guadalupe, Murcia, Spain, +34 968278566, kspyrou@ucam.edu

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INTRODUCTION

Futsal is a high-intensity intermittent indoor sport, in which players are exposed to repetitive high-demanding scenarios during match-play [1, 2]. A recent study [3] reported, through wearable technology (i.e., accelerometry) data, that futsal players perform around ~70 high-intensity accelerations, decelerations, and ~170 changes of direction during official games. Moreover, players have been found to cover around ~3700 m in a single match, of which ~135 m are spent on high-speed running actions (>18 km·h^{-1}) [4].

Of note, the type of games in futsal (i.e., official [OFF] and non-official [Non-OFF]) may influence match-play demands. Specifically, professional players have been reported to spend ~12% and ~5% of the whole game duration in high-intensity running and sprinting actions in a simulated match (i.e., 4 x 10-min), values lower than the ~14% and ~9% found during OFF competition [5, 6]. Likewise, the time of recovery between sprint bouts is higher in Non-OFF (i.e., ~40-s) when compared to OFF matches (~15-s) [6, 7]. Considering physiological parameters, a study [5] found that players spent 83% of the playing time above 85% of the maximum heart rate in OFF games as opposed to another investigation that reported that only 36% of the total time was spent at >80% of the maximum heart rate in Non-OFF matches [8]. For this reason, to prepare players adequately to cope with training and competition loads during the season, practitioners should be conscious that their athletes are exposed to dissimilar stress levels depending on the type of the game.

Regarding the quantification of the match demands, different methods (i.e., "average approach" or "worst-case scenarios" [WCS] methods) have been used to measure and analyze the mechanical stress that players are exposed to during the match. The WCS approach relates to the quantification of the most intense period of the game or training [11] and is becoming increasingly popular in team-sports, such as soccer [9, 10], rugby [11], Australian football [12], futsal [13], and field- and ice-hockey [14, 15], to assess fluctuations in match-demands by dividing time-play into discrete "epochs". The WCS may be considered more accurate to quantify the most intense periods of the game, because the "average approach" may overlook variations and obscure the most intense periods of the play [16].

Depending on the availability of wearable technology (i.e., GPS vs accelerometry) and sport (i.e., indoor vs outdoor), player load (PL), player load per minute (PL·min^{-1}), total distance, and high-speed running have been the most commonly investigated variables with time-windows ranging from 30-s to 10-min in length [9-14]. Within the WCS approach, the fixed-period method (FIX) was first developed [17], and consisted of splitting the time into fixed-periods (e.g., 1-30-s, 31-60-s, etc.). However, quantifying WCS by rolling average (ROLL) is considered more accurate, as this technique detects the exact period (e.g., 1-30-s, 2-31-s, etc.) in which players reached the highest intensity [18, 19]. For example, Fereday et al. [20] found that the FIX method underestimates the relative total and high-speed distances during match-play when compared to ROLL in soccer players [20]. Still, when it comes to futsal, literature is scarce about the quantification of WCS of different matches (i.e., OFF and Non-OFF) and using different methods (i.e., ROLL and FIX).

Therefore, this study aimed to compare and analyze the WCS in futsal considering: 1) OFF and Non-OFF matches; 2) calculated by two methods (i.e., ROLL and FIX); and 3) four different time-periods (i.e., 30-s, 1-, 3-, and 5-min). Due to futsal´s characteristics [2], we hypothesized that WCS would be higher: 1) in OFF when compared to Non-OFF matches; 2) when considering smaller (e.g., 30-s and 1-min) rather than larger time-epochs (e.g., 3- and 5-min), and 3) when calculated by ROLL in comparison to FIX.

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MATERIALS AND METHODS

STUDY DESIGN

An observation longitudinal study was designed. Match-play data from 26 games (i.e., 13 OFF and 13 Non-OFF) were collected using wearable technology (i.e., accelerometers) throughout the seasons of 2019/2020 and 2020/2021. OFF consisted of national (e.g., Liga Nacional de Fútbol Sala [LNFS]; 1st Division of Spain) or international (e.g., UEFA Champion League) games, and Non-OFF consisted only of friendly matches. Consistent with the LNFS rules, games lasted 40-min divided into two 20-min halves and separated by a 10-min break. Only on-court players (i.e., starters and substitutes) were monitored (i.e., 12 players). The study procedures did not influence or alter the match in any way. Four WCS time-periods (i.e., 30-s, 1-, 3-, and 5-min) were analyzed by the ROLL and FIX methods.

PARTICIPANTS

Twelve elite male futsal players (age: 26.7 ± 3.1 years old, body mass: 73.6 ± 5.4 kg, height: 1.77 ± 0.04 m, body fat: 8.9 ± 1.7%), competing in LNFS and the UEFA Futsal Champions League were monitored. By signing a professional contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

PROCEDURE

Instrumentation: The activity profile data were collected via Catapult Sport Optimeye S5 portable GPS units (Catapult Innovation; Melbourne, Australia) comprising a tri-axial accelerometer, a gyroscope, and a magnetometer, which provide data for inertial movement analysis at a sampling rate of 100 Hz. Previous research has reported this technology to be valid and reliable [21]. The devices were fitted to the upper back of each player using a specific vest under the athletes' jersey. To avoid potential inter-unit error, each player wore the same device throughout the seasons [22]. To represent the match-play cumulative load, data collection was initiated when players were in the locker room after the warm-up period, 10-min before starting the match, and concluded before the postgame cool-down. All data were analyzed by Catapult Sport Openfield software (Catapult Innovation; Melbourne, Australia) and exported to a custom-built Microsoft Excel spreadsheet for further analysis. PL consists of the sum of the accelerations across all axes of the internal tri-axial accelerometer during movement (100 Hz), applying the established formula and expressed as an arbitrary unit (a.u.) [23]. PL·min^{-1} divides the accumulated PL by time, and provides an intensity index [24].

Rolling Average and Fixed-Periods Length: To determine the WCS, data were extracted in each second interval for each player into a Microsoft Excel spreadsheet. ROLL was calculated by rolling time length of 30-s, 1-, 3-, and 5-min, (e.g., 1 – 30-s, 2 – 31-s, and so on) for the whole match, and by selecting the most intense passage for all the players individually (coefficient of variability [CV] 30-s: 10.9%; CV 1-min: 10.4%; CV 3-min: 10.4%; CV 5-min: 11.6%). FIX was obtained by splitting the total match into fixed-periods (e.g., 1 – 30-s, 31 – 60-s, etc.), from the start to the end of the game (CV 30-s: 12.1%; CV 1-min: 12.2%; CV 3-min: 13.1%; CV 5-min: 13.4%). For both methods, the highest intensity for every player in four time-windows (i.e., 30-s, 1-, 3-, and 5-min) was considered for analysis.

STATISTICAL ANALYSIS

The statistical analysis was performed using the Jamovi statistical package (2020; 1.6). Data are presented as mean and standard deviation (SD). Descriptive statistics were calculated for the types of game (i.e., OFF and Non-OFF), WCS duration (i.e., 30-s, 1-, 3-, and 5-min) and methods (i.e., ROLL and FIX). The assumption of normality in each variable was analyzed

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using the Shapiro-Wilk test. An independent T-Test was used to detect differences between WCS in OFF and Non-OFF games. A Non-Parametric Friedman repeated-measures ANOVA was completed to identify differences between the different WCS durations. A paired Sample T-Test was used to analyze the differences between the ROLL and FIX methods. Cohen's effect sizes (ES) with 95% confidence intervals (95% CI) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and very large (>2.0-4.0) [25]. The significance level was set at $p \leq 0.05$.

RESULTS

Figure 1 depicts the WCS (considering the PL·min^{-1}) in intervals of 30-s, 1-, 3- and 5-min and the differences between OFF and Non-OFF games and time-periods, calculated by ROLL. Significantly more intense WCS were found in OFF when considering 30-s (p = 0.001; ES [95% CI] = -0.53 [-0.79 – -0.28]) and 1-min (p = 0.001; ES [95% CI] = -0.47 [-0.72 – -0.21]) intervals in comparison to Non-OFF. Conversely, non-significant and trivial to small differences between game types were observed when analyzing 3-min (p = 0.060; ES [95% CI] = -0.23 [-0.48 – 0.01]) and 5-min (p = 0.605; ES [95% CI] = -0.06 [-0.31 – 0.18]) epochs. Regarding the different time-periods, 30-s intervals yielded greater WCS than all other periods (30-s – 1-min: p = 0.001; 30-s – 3-min: p = 0.001; 30-s – 5-min: p = 0.001), and 1-min intervals were found to be more intense than 3- and 5-min ones (1 – 3-min: p = 0.001; 1 – 5-min: p = 0.001). Finally, significant differences were obtained when comparing 3- to 5-min intervals (p = 0.001).

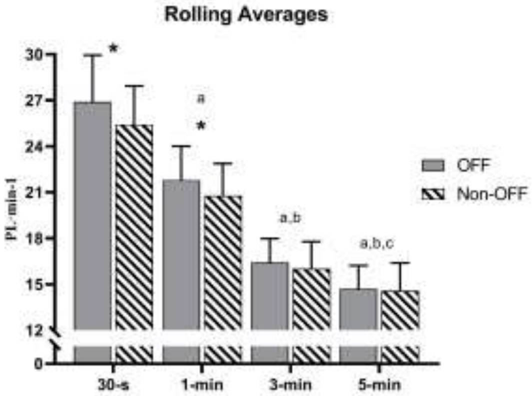

Fig. 1. Worst-case scenarios in official and non-official matches calculated over rolling-averages of 30-s, 1-min, 3-min and 5-min in length.

Values expressed as mean ± SD.
*p ≤ 0.05; significant difference between official and non-official analyzed by an Independent T-Test.
a: significantly different than the 30-s time-interval; b: significantly different than the 1-min time-interval;
c: significantly different than 3-min time-interval. OFF: official; Non-OFF: non-official.

Figure 2 presents the WCS (considering the PL·min^{-1}) during 30-s, 1-, 3- and 5-min intervals and the differences between OFF and Non-OFF games and time-epochs, calculated by the FIX. Significantly more intense WCS were found in OFF when considering 30-sec (p = 0.001; ES [95% CI] = -0.52 [-0.78 – -0.26]), 1-min (p = 0.001; ES [95% CI] = -0.49 [-0.75 – -0.23]), 3-min (p = 0.001; ES [95% CI] = -0.35 [-0.60 – -0.09]), and 5-min intervals (p = 0.001; ES [95% CI] = -0.40 [-0.66 – -0.15]) in comparison to Non-OFF. Regarding the different time-windows, 30-s presented greater WCS than all other periods (30-s – 1-min: p = 0.001; 30-s

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- 3-min: p = 0.001; 30-s - 5-min: p = 0.001) and 1-min intervals were found to be more intense than 3- and 5-min (1 - 3-min: p = 0.001; 1 - 5-min: p = 0.001). Finally, significant differences were obtained when comparing 3- to 5-min (p = 0.001).

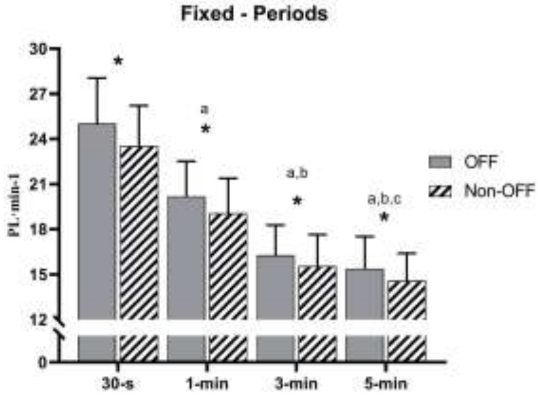

Fig. 2. Worst-case scenarios in official and non-official matches calculated over fixed-periods of 30-s 1-min, 3-min and 5-min in length.

Values expressed as mean ± SD.
*p ≤ 0.05; significant difference between official and non-official analyzed by an Independent T-Test.
a: significantly different than the 30-s time-interval; b: significantly different than the 1-min time-interval;
c: significantly different than 3-min time-interval. OFF: official; Non-OFF: non-official.

Table 1 describes the differences in WCS between the two methods (i.e., ROLL vs FIX). Significant and trivial to moderate differences were obtained between the two methods considering 30-s (p = 0.001; ES = 0.98), 1-min (p = 0.001; ES = 0.97), and 3-min (p = 0.001; ES = 0.18) periods. In contrast, non-significant and trivial differences were found for 5-min intervals (p = 0.107; ES = -0.18).

Table 1. The differences in the intensity calculated by rolling averages and fixed-periods among time-windows

Time -Window	$PL \cdot min^{-1}$ (a.u.)		Mean Diff (%)	p value	ES	95% CI
	Rolling	Fixed				
30-s	26.1 ± 2.84	24.2 ± 2.93	1.77 ± 0.12	0.001	0.98	0.83 - 1.13
1-min	21.2 ± 2.21	19.6 ± 2.39	1.70 ± 0.10	0.001	0.97	0.82 - 1.12
3-min	16.2 ± 1.68	15.9 ± 2.08	0.47 ± 0.10	0.001	0.18	0.06 - 0.30
5-min	14.6 ± 1.69	14.9 ± 2.00	-0.14 ± 0.11	0.107	-0.18	-0.30 - -0.05

Data presented as mean ± SD; *p ≤ 0.05; significant differences analyzed by a Paired Sample T-Test.
a.u.: arbitrary unit; CI: confidence interval; Diff: difference; ES: effect size; min: minutes; SD: standard deviation; s: seconds.

DISCUSSION

To our knowledge, this is the first study that compared the WCS between OFF and Non-OFF matches considering different time-periods in futsal. The main findings indicate that 1) the ROLL approach showed that OFF matches present higher intensity (i.e., $PL \cdot min^{-1}$) when short time-intervals (i.e., 30-s and 1-min) are considered in comparison to Non-OFF; however, no differences exist between games when analyzing large time-windows (i.e., 3- and 5-min); 2) significant differences were observed between matches in all time-periods when using the FIX method; 3) significantly higher WCS were determined as time-epochs increased in duration from 30-s to 5-min irrespective of the approach used; and 4) when compared to ROLL, FIX underestimates the WCS in 30-s, 1-, and 3-min intervals but not 5-min.

Match-play intensity during OFF competitions (e.g., LNFS and UEFA Futsal Champions League), as determined by PL·min^{-1} and calculated via ROLL, was found to be higher than during Non-OFF matches when considering the time-windows of 30-s and 1-min. This could be explained by the importance of the OFF games, in which "winning" is the main goal, and players are more likely to engage in maximal intensity efforts as opposed to friendly matches that are mainly focused on developing tactical, technical, and physical capacities [26]. Comparing acceleration, deceleration and metabolic power measures between official and friendly matches in soccer, differences in match activities were identified as well [27]. Moreover, it should be taken into account that Non-OFF games take place mainly during pre-season (i.e., a period of increased training loads) compared to the OFF ones that are held during the season, a period in which, in theory, players are closer to the peak of their performance. Notably, no difference in WCS was found between the matches as time-windows increased (e.g., 3- and 5-min intervals). It appears that larger time-epochs (i.e., >3-min) may obscure the most intense periods of the OFF competitions and overlook the "actual intensity" of these matches, possibly because futsal players barely spend >5-min on the court due to unlimited substitutions [28]. In brief, WCS calculated over longer intervals seem to be closer to the match average intensity obtained with the "average approach". From an applied perspective, 30-s and 1-min intervals should be analyzed when determining the WCS, as they are the only ones that allow discriminating between OFF and Non-OFF matches. Moreover, sports practitioners should be conscious that athletes are exposed to high physical stress during friendly matches but that the reached WCS are lower than those of the OFF competitions. Still, Non-OFF should be periodized accordingly, with sufficient recovery (essentially during the preparatory phase) as match time-exposure has been shown to cause more injuries than training time-exposure (i.e., 61.1 injuries/1.000 match hours vs 9.9 injuries/1.000 training hours) during the pre-season [29].

Regarding the different WCS computation methods, the FIX approach underestimated the intensity in futsal matches when compared to the ROLL in 30-s, 1-, and 3-min intervals. These results are in line with previous research from different team-sports [10, 17, 18]. For example, Cunningham et al. [18] found that the FIX method undervalued the maximum and high-speed running distance covered irrespective of the time-window (i.e., 60 - 300-s) in rugby players. Similar results were obtained in soccer players, with the FIX method underestimating the relative total and high-speed distances during match-play when compared to ROLL [20]. Interestingly, no significant differences between the two methods were found within the 5-min time-window herein. Again, this finding supports that the utilization of large time-periods to determine the WCS is not recommended, as they do not accurately portrait the game's most demanding passages. The intensity significantly declines as time extends from 30-s to 5-min by both the FIX and ROLL approaches. In applied settings, the WCS provide useful information for practitioners to optimize training and rehabilitation prescription. By better understanding the demands of the most intense periods, coaches can monitor training drills to ensure that players are exposed to such scenarios, particularly in technical-tactical training.

Whilst this is the first study that provides the WCS from an elite futsal team (UEFA Champion League Finalist) in different types of match, it is limited by the fact that only four WCS time-windows (i.e., 30-s, 1-, 3-, and 5-min) and one external load variable (PL·min^{-1}) were considered. Furthermore, this study was limited by the small number of players and the fact that only one team was recruited, which leads to analyzing only specific tactical behaviors and the style of the training. Other metrics, such as high-speed running distance

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or accelerations/decelerations, changes of direction, and collisions need to be considered while quantifying the WCS, as they may affect the most intense periods of the game [30]. A holistic approach to the quantification of the WCS that incorporates a range of external and internal load variables is needed in order to provide a better understanding of the most demanding passages during futsal competition because WCS may occur under multivariate conditions as mentioned above [30]. Regarding future research, it would be interesting to analyze how technical-tactical parameters can influence the WCS [30], how these are influenced by the context of situational variables (e.g. 5 vs 4 game in the court, home vs away advantage etc.), and the model of the game and the effectiveness of actions in the match [31]. Lastly, more research comparing the most intense periods of match-play between youth and professional matches to assist practitioners in planning and optimizing long-term player development is warranted.

WCS may provide coaches with useful information to optimize training and rehabilitation practices since a better understanding of the demands of the most intense periods of the game can be used to monitor training drills, particularly during technical-tactical training and allow a more progressive return to competition. From an applied perspective, based on the present data, sport practitioners are advised to use short time-periods (i.e., 30-s and 1-min) to quantify the WCS in futsal as these were the only ones found to be able to discriminate between different types of matches (i.e., OFF and Non-OFF). Conversely, larger time-periods (i.e., 3- and 5-min) appear to obscure the "actual intensity" to which the players are exposed. In addition, ROLL seems to be more accurate than FIX to detect the WCS in elite futsal matches.

CONCLUSIONS

In line with the initial hypothesis, OFF matches presented higher WCS when compared to Non-OFF competition, quantified by ROLL. However, through this computation method, differences between match types were identified only when short time-intervals (i.e., 30-s and 1-min) were used. Considering the FIX approach, significant differences in WCS between the OFF and Non-OFF games were found in all time-windows. Moreover, this method significantly underestimated the WCS from 30-s to 3-min, but not in the 5-min time-epoch compared to ROLL. Lastly, irrespective of the computation method, 30-s intervals were found to display the highest WCS and 5-min, the lowest.

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APPENDIX 5. Study 5**:** ANALYSIS OF THE COUNTERMOVEMENT JUMP VARIABLES ACCORDING TO COMPETITIVE LEVELS AND PLAYING POSITIONS IN FUTSAL.

Title of the article:

Analysis of the Countermovement Jump Variables according to Competitive Levels and Playing Positions in Futsal.

ABSTRACT

The aims of this study were to compare several countermovement jump (CMJ) kinetic variables between professional (PRO) and semi-professional (SEMI-PRO) futsal players and examine the differences amongst playing positions. CMJ performance from 56 male futsal players (25.2 ± 4.8 years; weight: 74.4 ± 6.4 kg) was analysed. Players were separated into PRO (n = 29; 27.0 ± 4.4 years; 75.4 ± 6.0 kg) and SEMI-PRO (n = 27; 22.7 ± 4.3 years; 73.1 ± 6.8 kg), and according to playing position: defenders (n = 16; 25.4 ± 3.7 years; 75.2 ± 6.0 kg), wingers (n = 26; 23.5 ± 4.5 years; 72.0 ± 6.9 kg), and pivots (n = 14; 28.0 ± 5.6 years; 77.8 ± 4.3 kg). Linear mixed models and effect sizes were used for the analyses based on the mean of two jumps for each variable. PRO players presented a higher center of mass (COM) displacement ($p = 0.002$, ES = 0.83), greater eccentric absolute ($p = 0.019$, ES = 0.61) and relative peak power ($p = 0.046$, ES = 0.52), and achieved greater eccentric peak velocities ($p = 0.004$, ES = 0.76) when compared to SEMI-PRO. Non-significant and trivial-to-small differences were observed in all the other CMJ variables according to the competitive level and playing position. Ecc capabilities (i.e., deeper COM displacement, greater Ecc absolute and relative peak power, and peak velocity) during vertical jump seem to differentiate PRO and SEMI-PRO players. However, CMJ variables do not discriminate amongst playing positions in futsal players.

Keywords: vertical jump, playing role, professional, team-sport.

INTRODUCTION

Futsal is a high-intensity intermittent sport in which, during match-play, players perform a great number of accelerations, decelerations, changes of direction, and explosive movements (16, 21, 22). For example, professional (PRO) futsal players have been shown to cover □3750 m, from which □135 m are performed at high-intensity running velocities (> 18 $km \cdot h^{-1}$), and complete ~5 accelerations and ~5 decelerations per min of "court time" (16). When compared to semi-professional (SEMI-PRO) competition (e.g., national state team), match physical demands are higher in PRO (e.g., international level team), with players covering a 42% greater total distance (□4300 m vs. □3000 m), completing a higher number of sideways or backward movements, and total overall activities (i.e., □470 vs. □310) (4). For this reason, well-developed physical capabilities play a crucial role in futsal, as they allow players to cope with the high-intensity demands of match-play.

Regarding neuromuscular performance, several studies (5, 6, 10, 14, 17, 18) found that PRO players significantly outperform SEMI-PRO in sprint, repeated sprint ability, standing broad jump, and change of direction and reactive agility tests. Remarkably, when it comes to jumping ability, PRO players have been reported to present similar values in countermovement jump (CMJ) height when compared to their SEMI-PRO counterparts (14, 18). However, CMJ height alone may not be sensitive enough to analyse the neuromuscular characteristics (i.e., explosiveness, fatigue, adaptation, etc.) of an athlete or to detect changes in the jump strategy (eccentric [Ecc] – concentric [Con] phase metrics) as a consequence of training or competition stimuli (1, 12). Therefore, a more comprehensive analysis of kinetic variables during the jump-land cycle in both PRO and SEMI-PRO futsal players is warranted, particularly taking into account that vertical force production plays a crucial role in athletic actions, such as sprinting and change of direction (13).

Considering players' positional demands, recent studies (9, 15, 19) demonstrated that match activities vary amongst positions (i.e., defenders [D], wingers [W], and pivots [P]). However, Caetano et al. (2) found no match demands positional differences in terms of sprint distance, peak velocity, recovery time between consecutive sprints, and number of sprints per minute. Interestingly, only one study (5) evaluated jumping ability (i.e., CMJ height) amongst playing positions in futsal, and reported non-significant differences when comparing goalkeepers, D, W, and P. Again, no additional CMJ metrics were analysed and futsal practitioners could benefit from a more thorough playing position-specific analysis of the neuromuscular performance to prescribe tailor-made training programs.

To date, no studies have analyzed the differences in CMJ kinetic variables according to competition level (i.e., PRO vs. SEMI-PRO) and playing position (i.e., D, W, and P). Thus, the aims of this study were to: 1) compare several CMJ metrics (i.e., CMJ height, center of mass [COM] displacement, flight-contraction time, modified reactive strength index [RSI_{mod}], and Ecc and Con duration, peak force, power, and velocity) between PRO and SEMI-PRO futsal players; and 2) analyze the differences in the above-mentioned metrics among playing positions (i.e., D, W, and P). According to the futsal match demands highlighted above, we hypothesized that: 1) PRO players would present higher performance in all CMJ metrics when compared to SEMI-PRO players; and 2) no differences on CMJ variables would be found between playing positions due to the tactical and technical characteristics of the sport (that make players more flexible to changing or rotating positions (20)).

MATERIALS AND METHODS

Study Desgin

This retrospective study was designed to compare the CMJ kinetics metrics between PRO and SEMI-PRO futsal players and amongst playing position. All players were evaluated after the pre-season period (i.e., September) during the seasons 2019-2020 and 2021-2022. CMJ data were collected following a standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., sub-maximal CMJ attempts). All evaluations were completed at the same time of the day, in the same facilities and following at least 24h of rest (i.e., training day-off) to avoid any acute or residual fatigue effects.

Subjects

Fifty-six male futsal players (age: 25.2 ± 4.8 years; body mass: 74.4 ± 6.4 kg) were recruited from 4 different teams and classified as PRO or SEMI-PRO according to their competitive level. The former group consisted of 29 players (age: 27.0 ± 4.4 years; body mass: 75.4 ± 6.0 kg) that competed in the 1st Division of Spain (Liga Nacional de Fútbol Sala [LNFS]) whereas the latter consisted of 27 players (age: 22.7 ± 4.3 years; body mass: 73.1 ± 6.8 kg) competing in either the 2nd Division of Spain (n = 8), or the 2nd B Division of Spain (n = 19). Furthermore, all players were separated per position as follows: 16 D (age: 25.4 ± 3.7 years; body mass: 75.2 ± 6.0 kg), 26 W (age: 23.5 ± 4.5 years; body mass: 72.0 ± 6.9 kg), and 14 P (age: 28.0 ± 5.6 years; body mass: 77.8 ± 4.3 kg). Goalkeepers were not included in this study. All the recruited players were free from injury and completed the standard training program of their respective team during the weeks preceding the test session. All players provided individual consent for data collection and study participation. All procedures were approved by the Local Ethics Committee and conducted according to the Declaration of Helsinki.

Methodology

Vertical Jump Test: Players performed the CMJ test on a portable force platform (Kistler 9286BA, Kistler Group, Winterthur, Switzerland). All data were exported and analyzed with a specific software (ForceDecks, Vald Performance, Brisbane, Australia). Players were required to perform a downward movement followed by a complete, rapid extension of the lower-limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement and athletes were directed to jump as high as possible and land close to the take-off point. They executed two maximal trials with 1 min rest and the mean of the two jumps was retained for analysis. The following variables were selected: CMJ height, COM displacement, flight-contraction time, RSI_{mod}, and Ecc and Con duration, peak force, power, and velocity. A total of 64 individual CMJ samples were analysed, as some participants were assessed both seasons.

Statistical analysis

The results are reported as estimated marginal means with 95% confidence intervals. Before running linear mixed models, boxplots and histograms were used to identify and exclude potentially influential data points. Following this analysis, residual plots were visually inspected to determine deviations from homoscedasticity or normality. All assumptions were met, and the normality of the residuals was also assessed using the Kolmogorov-Smirnov test. Linear mixed models were constructed to examine differences in CMJ variables according to competitive level and playing position, accounting for individual repeated measures. In all linear mixed models, competitive level (two levels) and playing position (three levels) were used as fixed effect and player as random effect with a random intercept and fixed slope. All assumptions were met, and the normality of the residuals was assessed using the Kolmogorov-Smirnov test. Pairwise comparisons were performed using post-hoc tests. The t statistics from the mixed model were converted into Cohen's d effect sizes and associated 95% confidence intervals. Effect sizes were interpreted as follows: <0.2, trivial; 0.20–0.59, small; 0.60–1.19, moderate; 1.2–1.99, large; and ≥2.0, very large (8). An alpha level of $p \leq 0.05$ was set a priori for statistical significance. All tests used in this study displayed high levels of absolute and relative reliability (i.e., intraclass correlation coefficients >0.90 and coefficients of variation <10%). All data were analysed using a statistical package (Jamovi, version 1.8, 2021).

RESULTS

Descriptive data and statistical analyses for CMJ kinetic variables according to competitive level are presented in Table 1. PRO players displayed greater COM displacement ($p = 0.002$, ES = 0.83, moderate), higher Ecc absolute ($p = 0.019$, ES = 0.61, moderate) and relative peak power ($p = 0.046$, ES = 0.52, small), and greater Ecc peak velocities ($p = 0.004$, ES = 0.76, moderate) when compared to SEMI-PRO. Non-significant and trivial-to-small differences were observed in all other CMJ variables (Ecc and Con phase) according to the competitive level.

*****Insert Table 1 around here*****

Descriptive data and statistical analyses for CMJ kinetic metrics according to playing position are presented in Table 2. No statistically significant differences ($p > 0.05$, ES ranging from 0.00 to 0.51, trivial-to-small) were observed in any of the CMJ variables when comparing among positions.

*****Insert Table 2 around here*****

DISCUSSION

The present study is the first comparing the CMJ kinetic metrics between PRO and SEMI-PRO futsal players and examining the differences among playing positions (i.e., D, W, and P). The main findings were that: 1) PRO players displayed superior Ecc capabilities, performing a higher COM displacement, generating greater absolute and relative peak power, and achieving greater peak velocities during the Ecc phase when compared to SEMI-PRO players; and 2) non-significant differences were found in any CMJ variables when considering playing positions.

Regarding jumping ability between competition levels, previous studies (14, 18) found that PRO players presented similar CMJ height values when compared to SEMI-PRO players, which is in line with the results obtained herein. This implies that CMJ height alone may not be the most suitable metric to discriminate players of superior competitive level or to be used for talent identification purposes. Conversely, when conducting a more comprehensive analysis of the kinetic variables during the jump-land cycle, PRO players displayed superior outcomes in several metrics of the Ecc (i.e., downward) phase (i.e., COM displacement, Ecc absolute and relative peak power, and Ecc peak velocity) than their lower-level counterparts. This difference could be explained, at least in part, by the higher number of matches and training sessions that PRO players are exposed to (i.e., □50 vs □30 games per competitive season and □6 vs □3 training sessions per week) when compared to SEMI-PRO. It is important to highlight that PRO players must cope with higher physical match-demands and had more years of experience performing specific movement patterns of the sport, thus, potentially developing superior Ecc capabilities, stretch-shortening cycle mechanisms and muscle-tendon properties compared to lower-level players (3, 7). Furthermore, it is noteworthy reporting that the observed differences according to the competitive level seem to be related to the ability to produce higher levels of forces on shorter time frames. Accordingly, despite no differences were observed in peak forces (both absolute and relative) between PRO and SEMI-PRO players, the former group was characterized by greater levels of power (both absolute and relative) and greater peak velocities during the Ecc phase. These abilities may play a key role during the futsal specific movements and contribute to be more efficient during the match-play from a physical point of view. From an applied perspective, the present results suggest that: 1) futsal players may benefit from performing Ecc-based and plyometric exercises, thus producing high levels of force within short time periods during the training sessions; and 2) a more comprehensive analysis of CMJ is recommended to evaluate and compare players from different competitive levels.

When comparing vertical jump ability amongst playing positions (i.e., D, W, and P), non-significant trivial-to-small differences were found in all CMJ metrics, which suggests that vertical jump seems not to differentiate players from different positions. These results support a previous study (5), that compared the CMJ height among goalkeepers, D, W, and P, and expand current knowledge by reporting no differences in a multitude of complementary jump-land variables. To some extent, the similar performances observed in all CMJ metrics among on-court players could be explained by the fact that, in futsal, playing positions are not as clearly define as in other indoor sports (e.g., basketball (23) or handball (11)). In fact, in futsal, tactical behaviours usually require players to adopt multiple playing positions during the same match (depending on the strategic plan of the team) which contributes to players having more similar physical performance profiles (20). Future studies should further investigate which are the most key determinants factors (e.g., technical-tactical, physical, and anthropometrical characteristics) for player´s position in futsal.

This study is limited by the fact that CMJ data were collected only at the end of the pre-season period (i.e., September), which does not allow us to conclude whether similar results would be obtained during the most crucial moments of the season (i.e., in-season). Moreover, when dividing the sample into playing position, a small sample size was analysed in each group, which may have precluded us from identifying clear between-group differences. Lastly, all the subjects competed in Spain and the results of this study should not be expand to other populations. Future research should incorporate more physical assessments, such as sprint, change of direction, isometric mid-tight pull, and strength deficit calculations to better characterize PRO and SEMI-PRO players' neuromuscular performance.

In conclusion, PRO players presented some superior Ecc capacity, as seen by the deeper COM displacement, the greater absolute and relative Ecc peak power, and the highest Ecc peak velocity when compared to SEMI-PRO players. By contrast, no significant differences were observed in any other CMJ variable. Lastly, non-significant differences were found amongst playing positions (i.e., D, W, and P) in futsal players, irrespective of the competitive level.

PRACTICAL APPLICATIONS

From an applied perspective, based on the present results, futsal strength and conditioning coaches are advised to incorporate plyometric and Ecc-overload exercises during the training sessions, as Ecc capabilities during vertical jump seem to discriminate between PRO and SEMI-PRO players. In addition, a more thorough analysis of the CMJ is recommended as neuromuscular changes that may exist, might not be expressed by CMJ height alone. Finally, players' position should not be defined taking into consideration the CMJs variables in futsal.

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Table 1. Comparison of countermovement jump variables according to competitive level.

Dependent variable (units)	EMMeans (95%CI)		ES (95%CI)	Interpretation	p value
	PRO	SEMI-PRO			
Jump height (cm)	36.6 (35.1; 38.1)	35.9 (34.3; 37.5)	0.16 (-0.33; 0.66)	*Trivial*	0.516
Flight – contraction time	0.753 (0.715; 0.791)	0.760 (0.720; 0.800)	0.06 (-0.43; 0.55)	*Trivial*	0.813
RSI_{mod} (m/sec)	0.514 (0.483; 0.546)	0.506 (0.473; 0.540)	0.09 (-0.41; 0.58)	*Trivial*	0.726
		Eccentric ("downward") phase			
Braking phase duration - Contraction Time	40.4 (38.6; 42.2)	41.1 (39.1; 43.1)	0.14 (-0.35; 0.64)	*Trivial*	0.577
COM Displacement (cm)	**32.7 (34.3; 31.2)**	**28.9 (30.6; 27.3)**	**0.83 (0.31; 1.34)**	***Moderate***	**0.002***
Dec phase duration (ms)	173 (161; 185)	155 (142; 168)	0.51 (0.01; 1.01)	*Small*	0.050
Duration (ms)	487 (461; 514)	476 (447; 504)	0.15 (-0.34; 0.65)	*Trivial*	0.544
Peak Force ABS (N)	1790 (1702; 1877)	1771 (1678; 1864)	0.07 (-0.42; 0.57)	*Trivial*	0.774
Peak Force REL (N)	23.6 (22.7; 24.5)	24.0 (23.1; 25.0)	0.15 (-0.35; 0.64)	*Trivial*	0.560
Peak Power ABS (W)	**1449 (1315; 1584)**	**1211 (1067; 1356)**	**0.61 (0.10; 1.11)**	***Moderate***	**0.019***
Peak Power REL (W)	**19.1 (17.4; 20.9)**	**16.5 (14.6; 18.4)**	**0.52 (0.01; 1.02)**	***Small***	**0.046***
Peak Velocity (m/s)	**1.32 (1.38; 1.25)**	**1.18 (1.25; 1.11)**	**0.76 (0.25; 1.27)**	***Moderate***	**0.004***
		Concentric ("upward") phase			
Duration (ms)	262 (251; 273)	249 (237; 261)	0.41 (-0.03; 0.91)	*Small*	0.107
Peak Force ABS (N)	1857 (1777; 1937)	1836 (1751; 1921)	0.09 (-0.40; 0.59)	*Trivial*	0.719
Peak Force REL (N)	24.5 (23.8; 25.3)	24.9 (24.1; 25.8)	0.18 (-0.31; 0.68)	*Trivial*	0.475
Peak Power ABS (W)	4041 (3866; 4216)	3930 (3745; 4114)	0.22 (-0.27; 0.72)	*Small*	0.384
Peak Power REL (W)	53.3 (51.5; 55.2)	53.5 (51.6; 55.4)	0.03 (-0.46; 0.53)	*Trivial*	0.898
Peak Velocity (m/s)	2.79 (2.74; 2.84)	2.77 (2.71; 2.82)	0.13 (-0.36; 0.62)	*Trivial*	0.609

Notes/Abbreviations: ABS: absolute; CI: Confidence Interval; COM: center of mass; Dec: deceleration; ES: effect size; EMMeans: estimated marginal means; REL: relative; RSI_{mod}: reactive strength index modified.
Bolded p value indicates statistically significant difference ($P < 0.05$).

Table 2. Comparison of countermovement jump variables according to playing position.

Dependent variable (units)	EMMeans (95%CI)			Main effect	W vs. D		W vs. P		D vs. P	
	W	D	P	p value	ES (95%CI)	p value	ES (95%CI)	p value	ES (95%CI)	p value
Jump height (cm)	37.3 (35.8; 38.9)	35.1 (33.1; 37.1)	36.3 (34.2; 38.5)	0.217	0.51 (-0.06; 1.09)	0.083	0.24 (-0.39; 0.87)	0.464	0.29 (-0.37; 0.96)	0.391
Flight – contraction time	0.777 (0.738; 0.816)	0.756 (0.706; 0.806)	0.736 (0.683; 0.789)	0.813	0.19 (-0.38; 0.76)	0.516	0.40 (-0.24; 1.03)	0.220	0.19 (-0.48; 0.85)	0.580
RSI_{mod} (m/sec)	0.532 (0.500; 0.565)	0.499 (0.457; 0.541)	0.499 (0.455; 0.544)	0.341	0.36 (-0.21; 0.93)	0.214	0.38 (-0.25; 1.01)	0.239	0.00 (-0.67; 0.66)	0.989
Eccentric ("downward") phase										
Braking duration - Contraction Time	41.3 (39.4; 43.2)	41.7 (39.3; 44.0)	39.3 (36.7; 41.9)	0.359	0.07 (-0.49; 0.64)	0.801	0.39 (-0.24; 1.03)	0.225	0.45 (-0.22; 1.12)	0.187
COM Displacement (cm)	30.9 (32.6; 29.3)	30.2 (32.3; 28.1)	31.3 (33.6; 29.1)	0.742	0.16 (-0.41; 0.73)	0.581	0.09 (-0.53; 0.72)	0.768	0.25 (-0.41; 0.92)	0.456
Dec phase duration (ms)	164 (152; 177)	161 (145; 177)	166 (149; 184)	0.892	0.11 (-0.46; 0.67)	0.717	0.05 (-0.58; 0.68)	0.876	0.15 (-0.51; 0.82)	0.649
Duration (ms)	478 (450; 506)	467 (432; 502)	500 (462; 538)	0.430	0.14 (-0.42; 0.71)	0.618	0.30 (-0.33; 0.93)	0.349	0.44 (-0.23; 1.11)	0.203
Peak Force ABS (N)	1741 (1650; 1831)	1766 (1650; 1881)	1835 (1711; 1958)	0.470	0.10 (-0.47; 0.67)	0.732	0.39 (-0.24; 1.03)	0.223	0.28 (-0.39; 0.94)	0.417
Peak Force REL (N)	24.2 (23.3; 25.2)	23.7 (22.6; 24.9)	23.5 (22.3; 24.8)	0.636	0.19 (-0.38; 0.76)	0.516	0.28 (-0.35; 0.91)	0.379	0.08 (-0.58; 0.74)	0.812
Peak Power ABS (W)	1288 (1148; 1429)	1374 (1196; 1551)	1329 (1137; 1521)	0.750	0.22 (-0.35; 0.79)	0.453	0.11 (-0.52; 0.74)	0.733	0.12 (-0.55; 0.78)	0.733
Peak Power REL (W)	18.1 (16.2; 19.9)	18.4 (16.1; 20.7)	17.0 (14.5; 19.5)	0.694	0.07 (-0.50; 0.64)	0.811	0.22 (-0.41; 0.85)	0.502	0.28 (-0.39; 0.94)	0.414
Peak Velocity (m/s)	1.26 (1.32; 1.19)	1.25 (1.34; 1.17)	1.23 (1.32; 1.14)	0.879	0.02 (-0.55; 0.58)	0.950	0.16 (-0.47; 0.79)	0.624	0.13 (-0.53; 0.80)	0.697
Concentric ("upward") phase										
Duration (ms)	253 (241; 264)	252 (237; 266)	263 (247; 279)	0.513	0.02 (-0.54; 0.59)	0.935	0.33 (-0.30; 0.97)	0.300	0.35 (-0.32; 1.01)	0.311

Peak Force ABS (N)	1800 (1717; 1883)	1834 (1729; 1940)	1904 (1791; 2017)	0.334	0.15 (-0.42; 0.72)	0.607	0.48 (-0.16; 1.11)	0.141	0.31 (-0.36; 0.97)	0.368
Peak Force REL (N)	25.1 (24.3; 25.9)	24.7 (23.7; 25.7)	24.4 (23.3; 25.5)	0.611	0.18 (-0.39; 0.74)	0.540	0.31 (-0.33; 0.94)	0.344	0.11 (-0.55; 0.78)	0.738
Peak Power ABS (W)	3928 (3748; 4108)	3929 (3698; 4159)	4099 (3854; 4345)	0.485	0.00 (-0.57; 0.57)	0.999	0.36 (-0.27; 0.99)	0.264	0.34 (-0.32; 1.01)	0.313
Peak Power REL (W)	54.8 (52.9; 56.7)	53.0 (50.6; 55.3)	52.6 (50.0; 55.1)	0.294	0.35 (-0.22; 0.92)	0.233	0.45 (-0.19; 1.08)	0.169	0.07 (-0.59; 0.74)	0.828
Peak Velocity (N)	2.81 (2.76; 2.87)	2.74 (2.67; 2.81)	2.78 (2.71; 2.85)	0.257	0.48 (-0.09; 1.05)	0.102	0.23 (-0.39; 0.86)	0.466	0.26 (-0.40; 0.93)	0.441

Notes/Abbreviations: ABS: absolute; COM displacement: centre of mass displacement; Dec: deceleration: EMMeans: estimated marginal means; REL: relative; RSI_{mod}: reactive strength index modified.

APPENDIX 6. Study 6**:** CHANGES IN NEUROMUSCULAR PERFORMANCE DURING PRE AND EARLY COMPETITIVE SEASON IN ELITE FUTSAL PLAYERS.

Changes in Neuromuscular Performance During Pre and Early Competitive Season in Elite Futsal Players

Konstantinos Spyrou,[1,2,3] Pedro E Alcaraz[1,3] Elena Marín-Cascales,[3] Daniel D. Cohen,[4,5] Tomás T. Freitas,[1,2,3,6]

1 UCAM Research Center for High Performance Sport, UCAM Universidad Católica de Murcia, Murcia, Spain;
2 Facultad de Deporte, UCAM Universidad Católica de Murcia, Murcia, Spain
3 Strength and Conditioning Society, Murcia, Spain;
4 Sports Science Center (CCD), Colombian Ministry of Sport (Mindeporte), Bogota, Colombia;
5 Masira Research Institute, University of Santander (UDES), Bucaramanga, Colombia;
6 NAR – Nucleus of High Performance in Sport, São Paulo, Brazil;

Correspondence: Konstantinos Spyrou, UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain, Campus de los Jerónimos, 30107, Guadalupe, Murcia, Spain, +34 968278566, kspyrou@ucam.edu

Running Head: Seasonal Changes in Performance in Futsal

Changes in Neuromuscular Performance During Pre and Early Competitive Season in Elite Futsal Players

ABSTRACT

This study aimed to investigate the variations on vertical jump and sprint performance during the first weeks of a futsal season. Eleven elite futsal players, competing in Spain's 1st Division over the season 2019-2020, performed two countermovement jumps (CMJ) on a force platform at three different timepoints: before the pre-season; immediately after the pre-season; and early in-season. A one-way repeated measure ANOVA with Post-hoc pairwise comparisons and effect sizes (ESs) were used. Non-significant and trivial changes were observed in CMJ_{height} ($p = 0.830$; ES = 0.12) among the three timepoints. However, significant and moderate positive changes amongst seasons were found in specific CMJ kinetic variables such as: modified reactive strength index ($p = 0.011$; ES = 0.60), eccentric (Ecc) peak force ($p = 0.011$; ES = 0.65), Ecc deceleration rate of force development ($p = 0.008$; ES = 0.60), Ecc duration ($p = 0.040$; ES = 0.89), and concentric ($p = 0.030$; ES = 0.45) and landing peak force ($p = 0.012$; ES = 0.68). A significant time interaction was observed in sprint performance ($p = 0.038$; ES = 0.58); however, non-significant and small-moderate changes were detected in sprint time when compared among periods. In conclusion, CMJ kinetic variables should be incorporated and analyzed alongside more standard measures (CMJ_{height}) to monitor performance in elite futsal players, as changes of substantial magnitude were observed in phase-specific metrics during the Pre-Season and the initial stages of the competitive calendar.

INTRODUCTION

Players´ physical capacities (i.e., muscular strength and power, speed, agility, aerobic and anaerobic fitness) play an important role in futsal match-play (24). This team-sport is intermittent by nature and is characterized by alternating low- to high- intensity actions, and by the large number of accelerations, decelerations, and changes of direction (20, 25). In addition, the total training and match-play stress imposed on futsal players, may vary during different periods of the season (19). For this reason, monitoring training and competition loads, and players' performance is common practice as reported by most practitioners in this sport (23).

Due to the long (and periodically match-congested) season in futsal, regularly assessing players' physical capacities is important as it allows coaches and sport scientists to make more informed decisions about specific training and recovery needs. In this context, Ribeiro et al. (21) recommended that vertical jump testing (i.e., countermovement jump [CMJ]) should be conducted as it may help understand players' neuromuscular readiness to compete which has implications for their match performance and, consequently, for the final team result. However, it is important to consider that CMJ height (CMJ_{height}) may not be sensitive enough to detect changes in stretch-shortening cycle performance or the contractile system function since evidence indicates that athletes may change their movement strategy to maintain (or even increase) jump height (3, 6, 7, 22). For example, in elite futsal players, Spyrou et al. (22) found that after a prolonged period of reduced training CMJ_{height} was not impaired, but specific eccentric (Ecc) and landing phase metrics were significantly altered. Therefore, a more comprehensive kinetic analysis of the CMJ force-time curve and its derivative impulse, power, velocity, displacement metrics could enhance the detection of positive or negative changes in athlete neuromuscular performance (11). Nevertheless, evidence describing how these CMJ metrics fluctuate across and within different phases of the season (e.g., Pre-Season [Pre_{se}] versus In-Season [In_{se}]) is still scarce and thus, more research on this topic is warranted.

On the other hand, studies (4-6, 8) from different team-sports have demonstrated that neuromuscular performance, such as sprinting and jumping ability, tends to be maintained or decrease In_{se} when compared to post Pre_{se} but few investigations have specifically evaluated this in futsal players (1, 16-18). For instance, Oliveira et al. (18) observed that repeated sprint ability was maintained from post Pre_{se} to the middle of the In_{se}. Another study, in a sample of Brazilian futsal players noted improved performance in the Yo-Yo Intermittent Recovery Level 2 and squat jump tests following a 4-week Pre_{se} period (17). However, the potential variation in a range of CMJ metrics during Pre_{se} and early In_{se} has not been studied in elite futsal players.

The present study aimed to investigate the fluctuations in neuromuscular performance (i.e., sprinting and jumping ability) across the initial 10 weeks of the season (including Pre_{se} and In_{se}) in a sample of elite futsal players. It was hypothesized that performance would increase during Pre_{se} and then, due to the demands of competition, be maintained or slightly decrease during the early In_{se} period.

METHODS

Experimental Approach to the Problem

This descriptive study was designed to assess the neuromuscular performance fluctuations (i.e., sprint time and CMJ jump-landing metrics) of professional male futsal players. The participants competed on *Liga Nacional de Fútbol Sala* (LNFS, 1st Division of Spain), during the season 2019-2020. The testing procedures were carried out at the beginning of Pre_{se} (July 30th), post Pre_{se} (September 10th), and after the first month of the competitive season (In_{se}) (October 14th)

(Figure 1). The players completed the same standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., two sub-maximal attempts in all tested exercises). All evaluations were completed in the team's facilities and performed following the same order (vertical jump and then sprint test). Each trial was separated by a 1-min rest interval, and 3-min were allowed between tests. The Pre_{se} evaluation was performed in the morning, at the beginning of the team´s 1^{st} training session (after off-season period), and all the other assessments were conducted in the morning after a recovery session day (i.e., Match Day +3) in order to minimize the potential influence of acute or residual fatigue induced by match-play on performance.

*****Insert Figure 1*****

Subjects

Eleven players (age: 28.0 ± 5.7 years old, body mass: 73.9 ± 8.0 kg, height: 1.79 ± 0.06 m) from a professional futsal team participated in this study. Athletes who did not complete all the assessments due to injuries were not included in the analysis. By signing a professional contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Ethics Committee and conducted according to the Declaration of Helsinki.

Procedures

Vertical Jump Test: Athletes performed a CMJ test on a portable force platform (Kistler 9286BA, Kistler Group, Winterthur, Switzerland). All data was exported and analyzed with proprietary software (ForceDecks, Vald Performance, Brisbane, Australia). Athletes were instructed to place hands on the hips and perform a rapid downward movement followed by a rapid extension of the lower-limbs and to jump as high as possible and land on the platform. No other instructions were given regarding landing technique or and countermovement depth – which was self-selected. Players performed two maximal trials with 1-min rest (ICC: = 0.87, CV: = 6.5%). The CMJ_{height} was derived from impulse-momentum equation (12), and the following additional CMJ jump-landing variables were analyzed: modified reactive strength index (RSI_{mod}), Ecc and concentric (Con) power, force, velocity, duration, Ecc deceleration (Dec) rate of force development (RFD), center of mass (COM) displacement, and landing peak force. The mean data of the two jumps used for analysis to reduce the random error (9).

Sprint Test: Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy), were positioned at the starting line and at 10-m. Players started from a standing position, 0.3-m behind the starting line and, when ready (without an investigator's signal), performed a maximal all-out linear sprint effort twice, with a 1-min rest (intraclass correlation coefficient [ICC] = 0.85, coefficient of variation [CV]: = 2.4%). The fastest time was considered for analysis. All athletes performed the test using the regular futsal shoes.

Statistical Analysis

Data are presented as mean ± standard deviation. Statistical analysis was performed using a statistical package (Jamovi, 2020; Version 1.8). One-way repeated measures ANOVA was used with Post-hoc pairwise comparisons conducted. Cohen's effect sizes (ESs) with 95% confidence intervals (95% CI) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2), large (>1.2-2.0), and very large (>2.0-4.0) (2). Significance level was set at $p \leq 0.05$.

RESULTS

Table 1 depicts the data for the CMJ kinetic variables analyzed. Significant and moderate-large increases were found in RSI_{mod} (p = 0.011; ES = 0.60), particularly, when comparing Pre_{se} to post Pre_{se} (*p* = 0.005; ES = 1.26; 95% CI = 0.44-2.05). Considering the downward ("Ecc") phase, a significant and moderately higher peak force (p = 0.011; ES = 0.65) was found post Pre_{se} when compared to Pre_{se} (*p* = 0.039; ES = 0.87; 95% CI = 0.15-1.55). Dec RFD (p = 0.008; ES = 0.60) significantly increased from Pre_{se} to post Pre_{se} (*p* = 0.044; ES = 0.84; 95% CI = 0.13-1.52) and In_{se} (*p* = 0.019; ES = 0.99; 95% CI = 0.25-1.71). Ecc duration (p = 0.04; ES = 0.89) significantly decreased when comparing In_{se} to Pre_{se} (*p* = 0.009; ES = -1.13; 95% CI = -1.89- -0.35).

In the upward ("Con") phase, a significant and moderately higher peak force (p = 0.030; ES = 0.45) was found post Pre_{se} when compared to Pre_{se} (*p* = 0.033; ES = 0.90; 95% CI = 0.18-1.59). A significant time effect was found for landing peak force (p = 0.012; ES = 0.68); however, non-significant and small-moderate changes were detected within periods. Non-significant and small-trivial changes were observed in all other analyzed variables.

*****Insert Table 1 here*****

Figure 2 presents the group and individual data for sprint performance across the first 10 weeks of the season. A significant time interaction was found for sprint time (*p* = 0.038; ES = 0.58); however, non-significant and small-moderate changes were detected in sprint time when

127 comparing Pre_{se} to post Pre_{se} ($p = 0.177$; ES = -0.58; 95% CI = -1.21-0.06), and In_{se} ($p = 0.821$; ES
128 = 0.18; 95% CI = -0.41-0.77), and post Pre_{se} to In_{se} ($p = 0.073$; ES = 0.75; 95% CI = 0.06-1.41).

129 ***Insert Figure 2 here***

130 **DISCUSSION**

131 The purpose of this study was to investigate potential changes in neuromuscular
132 performance in elite futsal players during the first 10 weeks of the season (i.e., Pre_{se} and early In_{se}).
133 The main findings were that: 1) jump height did not change during the Pre_{se} and in the early
134 competition season; 2) improvements in specific CMJ kinetic variables (i.e., RSI_{mod}, Ecc peak
135 force, Ecc Dec RFD and Con peak force) were observed post Pre_{se} which indicated an enhanced
136 neuromuscular status; 3) positive changes were also found in Ecc Dec RFD and Ecc duration when
137 comparing In_{se} to Pre_{se}; and 4) a significant time interaction was found in sprint time (that improved
138 post Pre_{se} and deteriorated in the early competitive season; however, changes between periods
139 were small and non-significant.

140 Regarding vertical jump performance, several CMJ metrics (i.e., RSI_{mod}, Ecc peak force,
141 Ecc Dec RFD, Ecc duration, and Con peak force) improved from Pre_{se} to early competitive season
142 (In_{se}). Of note, jump height was not altered during the first 10 weeks of the season while specific
143 CMJ metrics significantly changed post Pre_{se} and In_{se}. Similar results have been observed in other
144 team-sports in the sense that meaningful alterations in jump height were not detected in response

to loading or unloading, whereas a more thorough kinetic analysis of the CMJ revealed significant changes in neuromuscular function (3, 6, 7, 10, 13, 22). For example, in elite rugby players Lonergan et al (13) noted significant improvements in a number of CMJ variables such as Con duration, countermovement depth, Con impulse-100ms, Con RFD, Ecc Dec RFD, RSI_{mod}, and flight time-contraction time comparing the start and the end of the season. Regarding the current study, in the early In_{se} period, further but non-significant improvements were noted in Ecc Dec RFD, Ecc and Con duration, COM displacement. These results provide additional evidence that specific CMJ kinetic variables may be more sensitive than CMJ_{height} to detect changes in stretch-shortening musculotendinous or neuromuscular function. Furthermore, it is important to note that, across the two phases, the kinetic or "strategy" variables do not all follow the same pattern with respect to the magnitude and timing of change. For example, there was a significant large RSI_{mod} improvement during Pre_{se}, but the variable was stable during the early In_{se} period. In contrast, Ecc duration showed small to moderate improvements across both phases with these changes only achieving significance (relative to Pre_{se}) in the In_{se} assessment. This highlights the potential value of examining the component durations of a composite variable/indexes such as RSI_{mod} when monitoring short-term chronic adaptations. The "uncoupling" of trends across variables might also reflect a differential time course of response to loading and dissimilar loading patterns during Pre_{se} versus In_{se}. Cohen et al (3) previously noted such a pattern with respect to detraining, whereby differing durations and type of chronic unloading were associated with divergent profiles of change in CMJ kinetics. A thorough kinetic analysis of the CMJ might, therefore, provide sport practitioners with valuable information regarding athlete status and adaptations that may not manifest in jump height. It is also important to be aware that kinetic variables may differ in their response and sensitivity to loading, warranting exploration of trends within their sport and athlete cohort.

While the overall time interaction for sprint performance was significant, non-significant changes were detected when comparing the different phases. Specifically, players were faster after the Pre_{se} but performance deteriorated during early In_{se}, which aligns with previous studies (8, 14, 15, 18). For example, Arcos et al. (14) found non-significant improvements in acceleration (5-m) and sprint (15-m) time In_{se} compared to Pre_{se} in soccer players. A study in male professional players found a negative effect of a 9-week Pre_{se} conditioning program on sprint performance (15). Conversely, also in professional soccer players, Fessi et al. (5) reported significantly faster sprinting times post Pre_{se} when compared to both Pre_{se} and In_{se}. These inconsistencies could be explained by the different training programs carried out (the specifics of which were not described in these studies), the players´ profiles, such as chronological and training age or the competitive level, game congestion, and timing of tests relative to the game or training load. The present results suggest, from an applied perspective, that strength and conditioning coaches should frequently assess sprint capacity within the training sessions (using automatic timing systems) to facilitate the prescription of tailored-made training programs, with adequate sprint exposure and recovery.

This study is limited by its small sample size. Nevertheless, it is important to note that futsal teams are composed of 12 to 14 athletes, from which 11 (>80% of the team's players) were tested on three occasions during the first 10 weeks of the season (contemplating the Pre_{se}, post Pre_{se}, and In_{se}). Moreover, players' total training and match load, an important determinant of neuromuscular status, were not recorded during the 10-week period.

In summary, the present study adds to the body of evidence demonstrating that while CMJ_{height} may not change, longitudinally positive or negative alterations in neuromuscular performance may be detected by monitoring phase-specific CMJ kinetics. Changes in RSI_{mod}, Ecc peak force, Dec RFD, and duration, indicative of positive adaptations to Pre_{se} training, were observed in elite futsal players during the first 10 weeks of the season. Other CMJ metrics such as Ecc peak power and velocity, COM displacement, Con peak power, velocity, and duration, and landing peak force showed small positive but non-significant changes across the studied periods. Regarding sprint performance, a significant time interaction was found in sprint time but the post-hoc analysis was unable to decipher meaningful differences between the phases of the season as changes were small and non-significant.

PRACTICAL APPLICATIONS

Based on the current data, strength and conditioning coaches should implement a thorough analysis of the players' CMJ kinetics, as neuromuscular adaptations that may occur, might not be expressed by changes in CMJ_{height}. Metrics, such as RSI_{mod}, Ecc and Con peak force, Ecc duration, and Dec RFD may be more sensitive to neuromuscular chronic adaptations of futsal players to on- and off-court training, and competition. Finally, sport practitioners are advised to use a broad speed-power assessment during season to evaluate player´s physical adaptations and adjust the training session accordingly.

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Figure Legends

Figure 1. Representation of the study design.

Figure 2. Sprint time data between the different phases of the season.


Pre-Season
Post Pre-Season
In-Season
~5 Weeks
8-10 Training Sessions/Week
5 Friendly Matches
~5 Weeks
4-6 Training Sessions/Week
5 League Matches
LEGEND
Countermovement Jump Test
Sprint Test

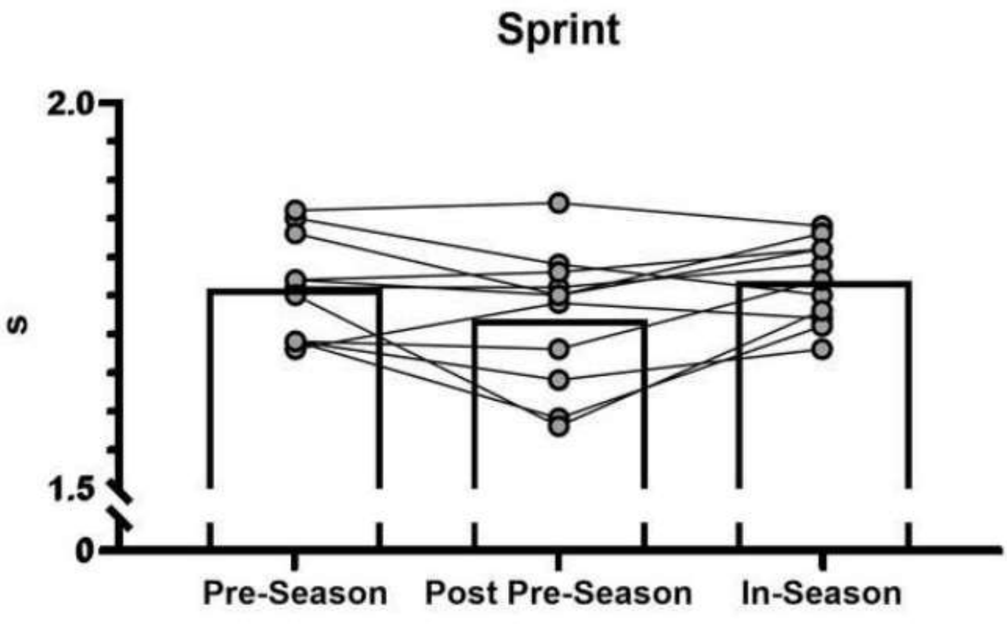
Sprint
2.0
1.5
0
s
Pre-Season
Post Pre-Season
In-Season

Table 1. Description of countermovement jump kinetic variables amongst different periods.

Variables	*Units*	*Pre-Season*	*Post Pre-Season*	*In-Season*	*p value*	*Pre-Season vs Post Pre-Season*		*Post Pre-Season vs In-Season*		*Pre-Season vs In-Season*	
						p	*ES*	*p*	*ES*	*p*	*ES*
CMJ $_{height}$	cm	37.3 ± 4.5	37.8 ± 5.2	37.1 ± 4.2	0.830	0.861	0.15	0.806	-0.19	0.994	-0.03
RSI $_{modified}$	**m/sec**	**0.49 ± 0.10**	**0.54 ± 0.09**	**0.54 ± 0.07**	**0.011***	**0.005***	**1.26**	1.000	0.00	0.102	0.69
ECCENTRIC ("DOWNWARD") PHASE											
Peak Power	W	1334 ± 511	1546 ± 378	1445 ± 323	0.158	0.120	0.66	0.479	-0.36	0.682	0.25
Peak Force	**N**	**1669 ± 354**	**1877 ± 272**	**1853 ± 248**	**0.011***	**0.039***	**0.87**	0.896	-0.13	0.082	0.73
Peak Velocity	m/s	-1.25 ± 0.28	-1.38 ± 0.17	-1.31 ± 0.17	0.107	0.113	-0.67	0.307	0.47	0.636	-0.27
Dec RFD	**N/s**	**6230 ± 2480**	**7778 ± 2516**	**7780 ± 2562**	**0.008***	**0.044***	**0.84**	1.000	0.00	**0.019***	**0.99**
Duration	**ms**	**507 ± 61**	**479 ± 49**	**454 ± 41**	**0.004***	0.237	-0.52	0.104	-0.68	**0.009***	**-1.13**
COM Displacement	cm	32.8 ± 3.1	33.1 ± 2.5	30.9 ± 3.8	0.075	0.960	-0.08	0.062	0.78	0.276	0.49
CONCENTRIC ("UPWARD") PHASE											
Peak Power	W	3871 ± 604	4017 ± 618	4050 ± 559	0.065	0.184	0.57	0.827	0.17	0.182	0.58
Peak Force	**N**	**1802 ± 228**	**1920 ± 251**	**1895 ± 224**	**0.030***	**0.033***	**0.90**	0.849	-0.16	0.144	0.62
Peak Velocity	m/s	2.80 ± 0.14	2.82 ± 0.17	2.81 ± 0.15	0.822	0.799	0.19	0.859	-0.15	0.992	0.03
Duration	ms	274 ± 64	250 ± 22	241 ± 24	0.181	0.514	-0.34	0.085	-0.72	0.321	-0.46
LANDING PHASE											
Peak Force	**N**	**5779 ± 1756**	**7371 ± 2463**	**6889 ± 1789**	**0.012***	0.056	0.80	0.536	-0.33	0.057	0.80

Values presented as mean ± standard deviation.

*p <0.05; significant differences analyzed by One-Way Repeated Measures ANOVA.

CI: confidence interval; COM: center of mass; Dec: Deceleration; ES: effect size; RFD: rate force development; RSI: Reactive Strength Index;

APPENDIX 7. Study 7. NEUROMUSCULAR PERFORMANCE CHANGES IN ELITE FUTSAL PLAYERS OVER A COMPETITIVE SEASON

Reference:

Spyrou, K., Alcaraz, P. E., Marín-Cascales, E., Herrero-Carrasco, R., Cohen, D. D., & Freitas, T. T. (2022). Neuromuscular Performance Changes in Elite Futsal Players Over a Competitive Season. The Journal of Strength & Conditioning Research, 10-1519.

Original Research

Journal of Strength and Conditioning Research

Neuromuscular Performance Changes in Elite Futsal Players Over a Competitive Season

Konstantinos Spyrou,[1,2,3] Pedro E. Alcaraz,[1,3] Elena Marín-Cascales,[3] Rubén Herrero-Carrasco,[4] Daniel D. Cohen,[5,6] and Tomás T. Freitas[1,2,3,7]

[1]UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain; [2]Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain; [3]Strength and Conditioning Society, Rome, Italy; [4]Research Group Murcia Soccer Federation, Murcia, Spain; [5]Sports Science Center (CCD), Colombian Ministry of Sport (Mindeporte), Colombia; [6]Masira Research Institute, University of Santander (UDES), Bucaramanga, Colombia; and [7]NAR, Nucleus of High Performance in Sport, São Paulo, Brazil

Abstract

Spyrou, K, Alcaraz, PE, Marín-Cascales, E, Herrero-Carrasco, R, Cohen, DD, and Freitas, TT. Neuromuscular performance changes in elite futsal players over a competitive season. *J Strength Cond Res* XX(X): 000–000, 2022—A professional futsal season imposes a great amount of physiological and mechanical stress on players. The main aim of this study was to examine the changes in neuromuscular performance qualities across the season. Ten professional male players performed a 10-m sprint, standing long jumps (SLJs), and countermovement jumps (CMJs) during the competitive season (i.e., every ~5 weeks from September to January). A one-way repeated measures ANOVA with post hoc pairwise comparisons and effect sizes (ESs) were used to analyze potential differences among these assessments. A significant and large decline was found in concentric peak power ($p = 0.040$; ES = 1.24). A nonsignificant and moderate decrease was observed in sprint ability ($p = 0.155$; ES = 1.03), CMJ height ($p = 0.175$; ES = 1.00), and SLJ distance ($p = 0.164$; ES = 1.03). Regarding other CMJ kinetic variables, nonsignificant and moderate changes were found. In summary, considering the neuromuscular performance tests and variables assessed, only concentric peak power in CMJ decreased significantly across the season; however, nonsignificant decrements were observed in sprinting time, SLJ, CMJ height, and other kinetic metrics. CMJ variables during the jump-land cycle should be incorporated alongside more traditional measures (e.g., jump height) to monitor performance during the season.

Key Words: five-a-side soccer, physical capacities, fatigue, competitive period

Introduction

Futsal is a high-intensity intermittent indoor sport, with high physical, technical, and tactical demands (23,27). The typical competitive season consists of ~50 regular matches including national (i.e., League and Cup) and international (i.e., European club tournaments and National Team) competitions over a span of ~7.5 months, with a frequency of 1–3 games per week. During a single match, futsal players cover a total distance of ~4,000 m, of which ~675 m are spent running (12–18 $km \cdot h^{-1}$) and ~130 m sprinting (>18 $km \cdot h^{-1}$), perform ~70 high-intensity accelerations and decelerations, and complete ~170 change of direction actions (24,28). In addition, they usually complete daily or twice-a-day sessions for games' preparation, covering as much as ~10 km (on average) at high and very high intensities during a typical weekly microcycle (14). Thus, a professional futsal season imposes a large physiological and mechanical stress on athletes (23,27). For this reason, training and competition loads can lead to not only acute neuromuscular fatigue (i.e., failure of the musculoskeletal system to maintain the required force and/or power output) (31) but also residual (i.e., 24–72 hour after exercise (25)) and potentially chronic fatigue (i.e., overtraining syndrome) (4), throughout the season, if appropriate individual tailor-made training programs (e.g., adjusting recovery times or limiting on-court weekly distance) are not considered.

Address correspondence to Pedro E. Alcaraz, palcaraz@ucam.edu.

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Neuromuscular performance monitoring (i.e., through jump, sprint testing, etc.) is often used as a practical tool to periodically evaluate the response to the training and competition stress that team-sport athletes are exposed to across the season (5,10). For example, decreases in countermovement jump (CMJ) performance (i.e., jump height) have been observed after soccer and rugby league matches (1,21). However, a number of studies (6,9,16) have shown that a more comprehensive analysis of kinetic variables during the jump-land cycle is needed to detect neuromuscular impairments associated with acute or residual fatigue, permitted when the test is performed with force platforms. Similarly, adaptive responses after periods of training (10,15) or detraining (6,26) may require a thorough analysis of selected CMJ metrics to identify alterations in neuromuscular status during the season that are not detected by monitoring jump height alone.

Several investigations (7,9,12,16,17,30,32) have examined neuromuscular performance at several time points during the sports season and shown that, overall, physical abilities tend to be maintained or decrease across the season. Legg et al. (17) detected trivial declines (effect size [ES] = −0.18) in CMJ performance and jump-land cycle during the competitive period in elite female basketball players. Nonetheless, there is also evidence demonstrating that physical capacities can be enhanced during the competitive period in team sports (11). For example, Gonzalez et al. (11) observed, in a sample of elite basketball players, that starters improved vertical jump power, quickness, and reaction time 17.15, 0.29, and 5.66% more, respectively, than nonstarters during the season. The variability in findings across these studies may be attributed to differences in the characteristics or demands of the sport, the level of the competition, the congestion of the competitive calendar (i.e., different number of matches per week), age (e.g., youth-amateur vs experienced), or contextual factors (e.g., player role: starters vs nonstarters) (9,11,16,32). Regarding futsal, few studies (2,22,29) have investigated potential changes in physical capacities across the season. Particularly, in professional futsal players, the influence of training and competition stress on sprint, horizontal and vertical jump performance, and CMJ kinetic variables (assessed multiple times across the competitive period) has not been examined.

Based on the above considerations, the aim of this study was to examine potential changes in speed-power-related outputs (i.e., sprint speed, standing long jump [SLJ] distance, and vertical jump height) and CMJ kinetic variables (derived from the eccentric, concentric, and landing phases) across the season in elite futsal players. Because of the prolonged and congested schedule in professional futsal, we hypothesized that performance across all metrics would decline as the season progressed.

Methods

Experimental Approach to the Problem

This longitudinal study was designed to track the neuromuscular performance (i.e., sprint time, CMJ kinetic variables, and SLJ distance) of elite male futsal players. The subjects competed on Liga Nacional de Fútbol Sala (LNFS; first Division of Spain) and UEFA Futsal Champions League over the 2019–2020 season, which spanned from August to March due to the COVID-19 restrictions imposed in Spain. The testing procedures were performed regularly during the season, at 4 time points (i.e., September [Sep], October [Oct], December [Dec], and January [Jan]) (Figure 1). In each session, all players completed the same standardized general warm-up protocol consisting of running-based activities, dynamic stretching, and core and lower-body activation exercises, followed by a test-specific warm-up (i.e., submaximal attempts in all tested exercises). The regular and congested weekly in-season training and game schedule is presented in Table 1. The evaluations were completed in the team's facilities during regular weeks (i.e., 1 game per week), 3 days after a match, in the following order: vertical jump, SLJ, and sprint test. Each trial was separated by a 1-minute rest interval, and 3 minutes were allowed between successive tests.

Subjects

Twelve players (age: 26.7 ± 3.1 years old, body mass: 76.7 ± 6.3 kg, height: 1.79 ± 0.06 m, body fat: 9.9 ± 1.2%) from an elite futsal team volunteered to take part in the study. Athletes who did not complete more than 1 assessment due to injury (i.e., as determined by the team's medical team that was responsible for the evaluation and recording of injuries according to the consensus statement of injuries in soccer (8), previously used in futsal (18)) were not included in the analysis. Two players did not meet these inclusion criteria; hence, 10 players were finally included in the study. By signing a professional contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the local ethics committee and conducted according to the Declaration of Helsinki.

Procedures

Sprint Test. Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy) were positioned at the starting line and at 10 m. Players started from a staggered position, 0.3 m behind the starting line and performed a maximal all-out linear sprint twice, with a 1-minute rest (intraclass correlation coefficient [ICC] = 0.71, coefficient of variation [CV]: = 4.5%). The fastest time was considered for analysis. All athletes performed the test on a wooden surface using regular futsal shoes.

Horizontal Jump Test. Athletes performed a SLJ, positioning their feet shoulder-width apart behind the starting line and the arms at the side of the body. A countermovement with arm swing was allowed before jumping. They were instructed to jump as far as possible in the horizontal direction, and the longest distance was recorded for analysis. Players performed a maximal effort three times with a 1-minute rest (ICC: = 0.92, CV: = 3.8%). Athletes were required to land with both feet simultaneously, and in case they fell forward or backward or touched the ground with one hand, the trial was considered invalid and repeated. The distance between the starting point and the heel of the rear foot measured by a tape to the nearest 1 cm was considered.

Vertical Jump Test. Athletes performed a CMJ on a portable force platform (Kistler 9286BA Kistler Group, Winterthur, Switzerland). Data were exported and analyzed using proprietary software (Python v.3.8.3). Athletes were required to perform a downward movement followed by a complete, rapid extension of the lower limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement, and athletes were directed to jump as high as possible and land close to the take-off point. They executed three maximal trials with a 1-minute rest between each (ICC: = 0.97, CV: = 5.9%). Jump height and multiple kinetic variables (i.e., eccentric and concentric peak power and velocity, duration, center of mass [COM]

Table 1
Typically normal and congested weekly schedule during the competitive period.*

Normal Week (1 Game)							
Day	1	2	3	4	5	6	7
AM	Recovery	Power-strength training	Power-strength training	Tec-Tact training	Tec-Tact training	Tec-Tact training	Game
PM		Tec-Tact training	Tec-Tact training				
Congested week (>2 Games)							
Day	1	2	3	4	5	6	7
AM	Power-strength training	Tec-Tact training	Game	Recovery	Tec-Tact training	Tec-Tact training	Game
PM	Tec-Tact training						

*Tac = tactical training; Tec = technical training.

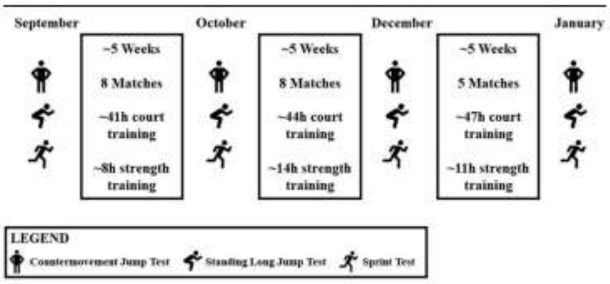


Figure 1. Representation of the study design.

displacement, landing peak force, and rate of force development [RFD] to peak force) from the best jump trial (according to the highest jump height) were retained for analysis.

Statistical Analyses

Data are presented as mean ± standard deviations (*SD*). Statistical analysis was performed using a statistical package (Jamovi, 2020; version 1.8). One-way repeated measures ANOVA was used, and post hoc pairwise comparisons conducted. Cohen's ESs with 95% confidence intervals (95% CIs) were computed to determine the magnitude of every paired comparison and classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), and very large (>2.0–4.0) (3). Significance level was set at $p \leq 0.05$.

Results

Figure 2 displays the group and individual data for sprint performance during the competitive period. A nonsignificant but moderate time effect was observed ($p = 0.155$; ES = 1.03). Specifically, the following results were found when comparing consecutive measurements: Sep–Oct ($p = 0.240$; mean difference [Dif_{mean}] = 3.9%; ES = 0.81; 95% CI: [0.07–1.52]), Oct–Dec ($p = 1.00$; $Dif_{mean} = -1.1\%$; ES = −0.18; 95% CI: [-0.83–0.47]), Dec–Jan ($p = 0.933$; $Dif_{mean} = 2.2\%$; ES = 0.20; 95% CI: [-0.50–0.90]), and Sep–Jan ($p = 0.081$; $Dif_{mean} = 4.7\%$; ES = 1.05; 95% CI: [0.20–1.85]).

Figure 3 presents the group and individual data for vertical and SLJ performance, and Table 2 depicts the data for selected CMJ kinetic variables. Regarding SLJ distance, a nonsignificant but moderate time effect was detected ($p = 0.164$; ES = 1.03). In detail, the following results were obtained: Sep–Oct ($p = 0.518$; $Dif_{mean} = -2.2\%$; ES = −0.36; 95% CI: [−0.99 to 0.28]), Oct–Dec ($p = 0.856$; $Dif_{mean} = 0.6\%$; ES = 0.14; 95% CI: [−0.51 to 0.79]), Dec–Jan ($p = 0.463$; $Dif_{mean} = -2.3\%$; ES = −0.54; 95% CI: [−1.27 to 0.21]), and Sep–Jan ($p = 0.376$; $Dif_{mean} = -3.9\%$; ES = −0.54; 95% CI: [−1.23 to 0.17]).

Considering vertical jump, a significant difference was found only in concentric peak power ($p = 0.040$; ES = 1.24), when comparing Sep to Oct ($p = 0.013$; Dif_{mean} −3.1%; ES = −1.26; 95% CI: [−2.09 to −0.40]). Moreover, a nonsignificant and moderate time effect was found for jump height ($p = 0.175$; ES = 1.00). Specifically, pairwise comparisons displayed the following results: Sep–Oct ($p = 0.300$; $Dif_{mean} = -3.6\%$; ES = −0.72; 95% CI: [−1.40 to −0.00]), Oct–Dec ($p = 0.595$; Dif_{mean} = 2.6%; ES = 0.53; 95% CI: [−0.17 to 1.22]), Dec–Jan ($p = 0.503$; $Dif_{mean} = -3.5\%$; ES = −0.51; 95% CI: [−1.24 to 0.23]), and Sep–Jan ($p = 0.479$; $Dif_{mean} = -5.1\%$; ES = −0.48; 95% CI: [−1.17 to 0.21]). In the rest of the analyzed variables during the CMJ concentric ("upward") phase, no significant changes were observed (peak velocity: $p = 0.142$; ES = 1.06; duration: $p = 0.938$; ES = 0.20). In the eccentric ("downward") phase, nonsignificant trivial to moderate decreases were observed in peak power ($p = 0.529$; ES = 0.78), peak velocity ($p = 0.238$; ES = 0.90), duration ($p = 0.316$; ES = 0.84), and COM displacement ($p = 0.554$; ES = 0.62). In the landing phase, there were nonsignificant and small to moderate changes in peak force ($p = 0.188$; ES = 1.00) and RFD to peak force ($p = 0.681$; ES = 0.50).

Discussion

The purpose of this study was to examine potential fluctuations in neuromuscular performance (i.e., sprint time, vertical jump height and selected kinetic variables, and SLJ distance) across the season in elite futsal players. Our main findings were (a) physical abilities (i.e., sprint time, SLJ distance, and vertical jump height) displayed nonsignificant but gradual declines throughout the competitive period, (b) concentric peak power was the only CMJ kinetic variable that decreased significantly, and (c) all other CMJ metrics considering the three phases (i.e., eccentric, concentric, and landing) showed nonsignificant small to moderate changes.

It seems that elite futsal players were not able to improve their sprinting ability throughout the competitive period (they sustained a gradual nonsignificant decline), aligning with previous

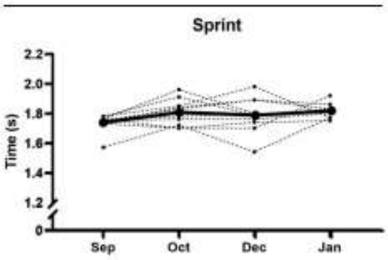
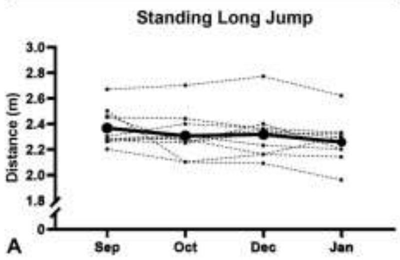


Figure 2. Sprint time data during the season. Bars represent mean values, and symbols and lines represent individual changes. Dec = December; Jan = January; Oct = October; Sep = September.



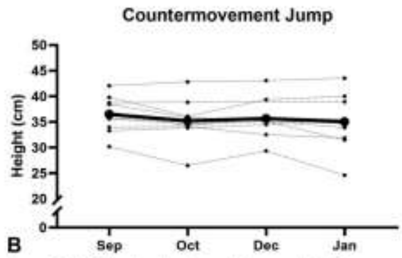


Figure 3. A) Standing long jump distance data. Bars represent mean values, and symbols and lines represent individual changes. Dec = December; Jan = January; Oct = October; Sep = September. B) Vertical jump height data. Bars represent mean values, and symbols and lines represent individual changes. Dec = December; Jan = January; Oct = October; Sep = September

findings in team-sports athletes (13,19,22). For instance, Oliveira et al. (22) observed that repeated sprint ability was maintained during in-season in elite Brazilian futsal players. In another study, Haugen et al. (13) found that sprint performance was superior at the off-season compared with in-season and pre-season. This phenomenon could be related to the concurrent training effect between power and endurance adaptations across the season and the insufficient recovery during congested periods (13,20). From an applied standpoint, it is important to note that in this study, despite not achieving statistical significance, sprint times were ~5% (ES = 1.05) higher (i.e., indicating lower performance) in Jan when compared to Sep, suggestive of a gradual decrease in maximal sprinting ability across the season. Periodic assessment of this quality during the competitive period could identify potential neuromuscular performance impairments, allowing individualized power-speed-oriented training prescription according to a player's competition and training cumulative load and response thereof.

Moderate but nonsignificant decrements in jumping ability were observed throughout the season. Mean CMJ height and SLJ distance values were, on average, 5.1% (ES = −0.48) and 3.9% (ES = −0.54) lower, respectively, in Jan when compared to Sep aligning with findings in other studies in team sports (7,16,17,32). For example, Kipp et al. (16) observed that although team-average jump height did not change over the course of the season, in individual players, greater competition volume was associated with decreased CMJ height in female collegiate volleyball players. In professional ice hockey, a significant decrease in CMJ height across the season was found (9). By contrast, an investigation in NBA players revealed that, in players with greater playing minutes, repetitive vertical jump power and lower-body power increased during the competitive period (11). These divergent results could be explained by the characteristics/loading demands of the sports investigated (e.g., basketball vs ice hockey) and timing of the retest (i.e., pre-season, early season, mid-season, and late season, 36 hours after the last game vs before the start of the regular season and at the end of the regular season). In this study, jump height had slight, steady but nonsignificant decreases over the season. Nevertheless, from a practical perspective, it is important to acknowledge that each athlete responds individually to the applied stress, and by identifying abnormal responses, tailored-made training strategies may then be implemented to avoid/mitigate detrimental effects.

A comprehensive kinetic analysis of the CMJ identified a significant and large (ES = 1.24) decline in concentric peak power and small to moderate but nonsignificant effects in eccentric and landing phase-specific metrics (i.e., peak power and velocity, RFD, duration, etc), with the largest differences observed between Sep and Jan (Table 2). Significant changes in CMJ kinetic variables have been noted in studies in other team-sports athletes (9,16). In professional ice-hockey athletes, Gannon et al. (9) found that concentric peak velocity and COM displacement decreased in the late season when compared to the early season. Moreover, the concentric power decrements may reflect potential residual fatigue or the muscular skeletal system that negatively affect power production capabilities as the season progresses (6). Therefore, sports practitioners, coaches, and scientists should be aware that a thorough kinetic analysis of the CMJ might provide valuable information regarding the neuromuscular status of the athletes that may not be obtained when analyzing jump height alone (10,26). Finally, frequent evaluations during the competitive period may allow to describe better the effects of training or competition stress on jump-landing cycle fluctuations. We also noted that although CMJ height steadily decreased, eccentric (i.e., peak power and velocity, duration, and COM displacement) and landing (i.e., peak force and RFD to peak force) metrics showed positive trends during specific time points of the season.

There are limitations to this study that must be acknowledged. First, the season was abbreviated because of the COVID-19 pandemic (i.e., interrupted in March 2020 and recommenced directly with play-off games in June 2020). Therefore, the duration of the competition season was 6 months instead of the typical ~8-month season. Second, a small sample size was analyzed. Nevertheless, it is important to note that futsal teams are composed of only 12–14 players, from which 10 were tested during the season, representing >80% of the team's players. Third, subject's total playing time, which could mediate the fluctuations of the neuromuscular performance throughout the season, was not recorded. Finally, a more comprehensive testing battery (e.g., including change of direction tasks, unilateral/bilateral drop jumps, or maximal strength assessments) and more frequent evaluations (e.g., weekly tests) could allow to describe better the effects of training or competition stress on neuromuscular performance during the competitive period. Nevertheless, the aim of the study was to evaluate the chronic adaptations on neuromuscular performance during in-season, with tests conducted at a moment of the week (i.e., three days after competition) at which point the residual fatigue effects associated with match-play are limited (25).

In summary, considering the neuromuscular performance tests and variables assessed, only concentric peak power in CMJ was decreased significantly across the season. However, gradual and nonsignificant decrements were observed in other assessments

Table 2

Description of horizontal and countermovement jump kinematic and kinetic variables during the season.*†

Variables	Units	Sept	Oct	Dec	Jan	p	Split periods: Sept–Oct %	Sept–Oct ES	Oct–Dec %	Oct–Dec ES	Dec–Jan %	Dec–Jan ES	Total period: Sept–Jan %	Sept–Jan ES
SLJ	cm	2.37 ± 0.14	2.31 ± 0.17	2.32 ± 0.20	2.26 ± 0.17	0.164	−2.2	−0.36	0.6	0.14	−2.3	−0.54	−3.9	−0.54
CMJ_{height}	cm	36.5 ± 3.48	35.2 ± 4.12	35.6 ± 3.87	35.0 ± 5.54	0.175	−3.6	−0.72	2.6	0.53	−3.5	−0.51	−5.1	−0.48
$RSI_{modified}$	m/s	0.51 ± 0.09	0.47 ± 0.10	0.48 ± 0.08	0.50 ± 0.12	0.126	−7.9	−0.71	7.4	0.46	0.0	0.03	−4.6	−0.28
Eccentric ("downward") phase														
Peak power	W/kg	−18.1 ± 4.63	−18.1 ± 6.24	−17.2 ± 4.79	−20.1 ± 5.88	0.529	−1.3	0.04	5.2	−0.10	11.7	−0.65	5.2	−0.48
Peak velocity	m/s	−1.28 ± 0.15	−1.21 ± 0.25	−1.30 ± 0.20	−1.34 ± 0.17	0.238	−5.5	0.34	13.0	−0.62	2.3	−0.09	3.0	−0.32
Dec duration	ms	165 ± 35.0	176 ± 43.0	171 ± 36.0	163 ± 30.0	0.316	6.5	0.38	−3.7	−0.31	2.1	0.16	4.3	0.23
COM displacement	cm	31.3 ± 4.11	30.1 ± 3.57	32.6 ± 4.06	30.5 ± 3.18	0.554	−3.4	−0.39	7.6	0.62	−2.6	−0.36	−0.8	−0.00
Concentric ("upward") phase														
Peak power	W/kg	54.7 ± 5.24	53.0 ± 5.55	51.9 ± 4.61	52.9 ± 6.67	**0.040‡**	−3.1	−1.26	−0.4	−0.34	−1.0	0.16	−4.8	−0.93
Peak velocity	m/s	2.80 ± 0.12	2.76 ± 0.14	2.78 ± 0.12	2.76 ± 0.18	0.142	−1.6	−0.81	1.3	0.74	−1.3	−0.49	−1.7	−0.46
Duration	ms	259 ± 27.0	259 ± 28.0	266 ± 27.0	259 ± 26.0	0.938	0.1	−0.00	1.9	0.10	0.5	0.11	2.2	0.16
Landing phase														
Peak force	N/kg	105 ± 28.7	104 ± 41.3	92.4 ± 19.5	89.1 ± 17.4	0.188	−1.0	−0.02	−6.3	−0.43	0.5	−0.05	−18.1	−0.70
RFD to peak force§	N/s/kg	3,721 ± 3,003	3,398 ± 2,294	3,685 ± 2,884	2,784 ± 1948	0.681	−3.4	−0.25	3.3	0.08	9.0	−0.09	−15.8	−0.50

*CI = confidence interval; COM displacement = center of mass; Decel = deceleration; RFD = rate force development; RSI = reactive strength index; SLJ = standing long jump.
†Values presented as mean ± SD.
‡$p < 0.05$; significant differences analyzed by one-way repeated measures ANOVA.
§RFD to peak force: average RFD calculated from landing [time 1] to landing peak force [time 2]. Impulse, force, RFD, and power variables are expressed relative to body mass.

(e.g., sprint time [4.7%; ES = 1.05], SLJ distance [3.9%; ES = −0.54]) and vertical jump outcomes (e.g., CMJ height [5.1%; ES = −0.48]). Other jump-landing phase cycle metrics (i.e., eccentric peak power and velocity, duration, COM displacement, landing peak force, and RFD to peak force) showed positive small to moderate fluctuations throughout the season. The accumulated training and game demands may preclude futsal players from increasing gross sprinting and jumping performance (such as height or power) during the competitive period.

Practical Applications

Monitoring elite futsal players' performance is crucial not only for individual athlete care but also for the team's success. From an applied perspective, monitoring practices should consider the individual athlete's response to the match and training stress they are exposed to, to identify the need for adjustments to competition or training load/recovery and, ultimately, to minimize potential performance decrements. Based on the current data, practitioners are encouraged to perform a broad speed-power assessment including a more thorough kinetic analysis of the CMJ as it might provide valuable information regarding the neuromuscular status of the athletes that may not be identified when monitoring jump height alone. Specifically, concentric peak power should be considered a variable of interest as, in the current study, it was the only CMJ metric that decreased significantly across the season.

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APPENDIX 8. Study 8: EFFECTS OF THE COVID-19 LOCKDOWN ON NEUROMUSCULAR PERFORMANCE AND BODY COMPOSITION IN ELITE FUTSAL PLAYERS

Reference:

Spyrou, K., Alcaraz, P. E., Marín-Cascales, E., Herrero-Carrasco, R., Cohen, D. D., Calleja-Gonzalez, J., ... & Freitas, T. T. (2021). Effects of the COVID-19 lockdown on neuromuscular performance and body composition in elite futsal players. The Journal of Strength & Conditioning Research, 35(8), 2309-2315.

Original Research

Journal of Strength and Conditioning Research

Effects of the COVID-19 Lockdown on Neuromuscular Performance and Body Composition in Elite Futsal Players

Konstantinos Spyrou,[1,2] Pedro E. Alcaraz,[1] Elena Marín-Cascales,[3] Rubén Herrero-Carrasco,[4] Daniel D. Cohen,[5,6] Julio Calleja-Gonzalez,[7,8] Lucas A. Pereira,[9,10] Irineu Loturco,[9,10,11] and Tomás T. Freitas[1,2,9]

[1]UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain; [2]Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain; [3]Strength and Conditioning Society, Rome, Italy; [4]Research Group Murcia Soccer Federation, Murcia, Spain; [5]Sports Science Center (CCD), Colombian Ministry of Sport (Mindeporte), Bogotá, Colombia; [6]Masira Research Institute, University of Santander (UDES), Bucaramanga, Colombia; [7]Laboratory of Analysis of Sport Performance, University of Basque Country, Vitoria, Spain; [8]Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia; [9]NAR—Nucleus of High Performance in Sport, São Paulo, Brazil; [10]Department of Human Movement Sciences, Federal University of São Paulo, São Paulo, Brazil; and [11]Department of Sport and Exercise, University of South Wales, Pontypridd, Wales

Abstract

Spyrou, K, Alcaraz, PE, Marín-Cascales, E, Herrero-Carrasco, R, Cohen, DD, Calleja-Gonzalez, J, Pereira, LA, Loturco, I, and Freitas, TT. Effects of the COVID-19 lockdown on neuromuscular performance and body composition in elite futsal players. *J Strength Cond Res* XX(X): 000–000, 2021—Recent world events (i.e., COVID-19 pandemic) led to an unparalleled situation in sports. Players were forced to stay at home for a prolonged period and not allowed to use their team's training facilities or even exercise outdoors. The main aim of this study was to examine the effects of the COVID-19 lockdown on neuromuscular performance and body composition in futsal players. Ten elite male players performed a 10-m sprint, horizontal and vertical jump, and body composition measurements before and after the quarantine (i.e., 70 days). Pre-post confinement differences in horizontal jump distance, countermovement jump variables, sprinting time, and body composition were analyzed by a paired sample *t*-test and effect sizes (ESs). A large and significant decline was observed in sprint ability ($p = 0.004$; ES = 1.31). Small and nonsignificant differences were found in horizontal jump performance ($p = 0.243$; ES = −0.39). Nonsignificant differences were observed in countermovement jump (CMJ) height ($p = 0.076$; ES = −0.63) but moderate-to-large significant declines were found in CMJ eccentric deceleration impulse, rate of force development, peak power, velocity, and landing peak force ($p \le 0.05$; ES = −0.52 − 1.23). Finally, trivial and nonsignificant differences were obtained on body composition parameters. In summary, sprint performance and specific CMJ kinetic variables were significantly affected by long-term reduced training, whereas vertical jump height and horizontal jump distance and body composition were not. Practitioners are advised to implement efficient sprint-oriented and eccentric-oriented training strategies to optimize return to competition after prolonged detraining periods.

Key Words: five-a-side soccer, detraining, physical capacities

Introduction

Futsal is a high-intensity intermittent indoor sport, with high physical, technical, and tactical demands during match-play (1,3,5,6,27). In competitive scenarios, futsal players have been shown to cover an average of ~4,313 m during a single match, with high-intensity running corresponding to 13.7% and sprinting to 8.9% of the efforts performed (3). Moreover, players may complete ~30 sprints, in sequences of 2, 3, and 4 sprints, with 15–60-second rest intervals (5). These data highlight the importance of players having well-developed neuromuscular capabilities that enable them to successfully perform actions that require high-power outputs (e.g., sprints, jumps, and rapid changes of direction) and cope with the high-intensity demands of competition. In this regard, jumping and sprinting ability are commonly used as monitoring tools to evaluate players' performance and fatigue levels throughout the season (7,10,18).

Regarding professional futsal, recent world events have resulted in an unparalleled situation with important implications for elite players. At the beginning of 2020 (January–March), sport leagues and tournaments worldwide (e.g., European soccer and futsal national leagues or the Olympic Games) were postponed or canceled because of a novel virus: SARS-CoV-2 (COVID-19). The uncontrolled spread of the virus caused thousands of cases of respiratory problems globally leading the World Health Organization to declare COVID-19 a pandemic (23). Most European countries imposed a mandatory confinement that, among other occupations, affected professional sports. As a consequence, athletes were forced to stay at home and were not allowed to use the team's training facilities. To face this unprecedented scenario during the in-season period, coaches and sports scientists provided several training recommendations in an attempt to minimize the detrimental effects caused by the lockdown on physical performance (15).

Address correspondence to Pedro E. Alcaraz, palcaraz@ucam.edu.

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Nevertheless, the actual effects of home confinement and long-term reduced training cannot be properly comprehended until players return to their normal activities.

According to Mujika and Padilla (20,21), detraining is defined as the total or partial loss of anatomical, neuromuscular, and physiological adaptations due to training reduction or cessation. Training cessation refers to the partial or complete pause of a precise training plan; reduced training consists on a non-progressive reduction of the training that may maintain or improve performance (20). On this topic, Koundorakis et al. (17) observed that after a long-term (i.e., 6 weeks) training cessation highly trained soccer players' neuromuscular responses (i.e., sprint and vertical jump) were negatively affected. Similarly, decreased eccentric knee extension force, electromyographic activity of the vastus lateralis during an isometric test, and changes in type II fiber areas were reported after 2 weeks of training cessation in power athletes (12). Moreover, fiber type transitions (i.e., from fast type II to slow type I fibers) have been shown to occur after detraining in several studies (16,22,30). Thus, it seems that sudden decreases in training load for an extended period may be detrimental to performance, particularly in highly trained individuals. However, a situation as the one caused by the COVID-19 (which resulted in professional athletes spending more than 60 days without adequate training, resources, and competition stimuli) is unprecedented, and therefore, its effects on athletic performance are unknown, particularly in futsal players. In fact, studies on this topic focused mainly on elite soccer. For example, an investigation with Brazilian players revealed significant decreases in countermovement jump (CMJ) and sprint (i.e., 10- and 20-m) performance after the quarantine (11). Similarly, another study (8) demonstrated that, although isolated resistance circuit and aerobic training was able to maintain CMJ height, reactive strength index, and peak concentric and eccentric power during the lockdown, other specific eccentric (i.e., downward) and landing phase kinetic variables were significantly altered in elite soccer players. As such, additional research in neuromuscular performance components is still needed to better understand the effects of long-term training cessation.

Body composition (i.e., body mass, fat percentage, and muscle mass) is another important aspect to consider in professional athletes as it plays a crucial role in competitive performance (29). A decrement on physical activity levels reduces energy expenditure that, in turn, may increase body fat (13). Previous research conducted with professional soccer players found that body fat and body mass were negatively affected after the transition phase of the season (17). However, to understand the effects of an unusual and prolonged home confinement on body composition in top-level athletes (e.g., elite futsal players), further investigation is warranted.

This study aimed to investigate the effects of a 70-day reduced training period forced by the COVID-19 quarantine on speed-power–related capacities (i.e., sprint acceleration, horizontal jump, and vertical jump) and body composition (i.e., body mass, body fat percentage, and muscle mass) of elite futsal players. Because of the prolonged period of specific reduced training, we hypothesized that athletic performance and body composition would be negatively affected by the lockdown period.

Methods

Experimental Approach to the Problem

This pre-post quasi-experimental study aimed to investigate the changes on speed-power–related performance and body composition after the home confinement period caused by the COVID-19 pandemic. In Spain, the lockdown was announced on March 14, 2020. The prelockdown performance had been previously assessed on March 3, 2020, (as part of the physical testing procedures applied monthly to the futsal players during the in-season period) and the postlockdown evaluation was conducted on May 13, 2020 (i.e., 70 days later). The preconfinement body composition data were collected on March 2 and postconfinement assessments were conducted on May 12, 2020 (i.e., after 70 days). Pretest evaluations were completed for all players collectively, whereas, on posttest, players reported to the laboratory individually (3 players were assessed each hour, between 09:00 and 13:00 hours), according to the governmental guidelines. All players were familiarized with the testing procedures because of their regular routines in our facilities. Players completed the same standardized general warm-up protocol consisting of running-based activities, dynamic stretching, core and lower-body activation exercises, followed by a test-specific warm-up (i.e., submaximal attempts in all tested exercises). Tests were performed on the following order: vertical jump, horizontal jump, and sprint acceleration test. The 10-m sprint test was selected because futsal match activity profiles have shown that the average sprinting distance is ~10.5 m (27). Each trial was separated by a 1-minute rest interval, and 3 minutes were allowed between successive trials and tests.

During the lockdown, each player followed an individualized nutritional plan developed by the team's nutritionist and adjusted every 2 weeks. To keep prequarantine body composition parameters, players recorded their body mass twice per week and reported it to the team's nutritionist. The Harris-Benedict's equation (14) was used to measure energy expenditure and determine each player's energy intake (i.e., should be the same as the energy expenditure). In addition, all players completed a semi-structured maintenance training program (Table 1) comprising exercises using only the body mass as resistance (e.g., vertical and horizontal jumps, half and full squats, lunges, push-ups, etc.). Athletes were instructed to perform these exercises 2–3 times per week, completing 2 or 3 sets of 6–8 (jumps) and 10–12 (squats and lunges) repetitions. Importantly, and as shown in Table 1, despite completing the maintenance program, players experienced a considerable decline in all type of fast stretch-shortening cycle actions during the lockdown (i.e., due to the lower training intensity and frequency and to the lower exposure to jumping and other explosive actions characteristic of futsal training and match-play). All players confirmed that they did not seek any professional advice outside of the team's coaching staff nor did they follow any prescribed training by other practitioners. In this sense, during the quarantine period, athletes were considered to be on a long-term reduced training phase.

Subjects

Players from an elite futsal team (i.e., a 12-player squad) volunteered to take part in the study. Two athletes did not complete the last assessment prequarantine because of minor injuries and were not included in the analysis. Therefore, 10 elite male futsal players (mean ± *SD*; age: 26.7 ± 3.1 years old, body mass: 76.0 ± 6.6 kg, height: 1.78 ± 0.06 m) participated in this study. Futsal players competed in the Spanish National League (LNFS) and were qualified to play the UEFA Futsal Champions League Final. Therefore, the high level of the players in this study sample can be confirmed. All athletes involved were free of injury before the

Table 1
Models of the training structure during the competitive season and the lockdown period.*

Training strategy	Resistance training	RST	Plyometric
Competitive season			
Exercise type	Traditional and ballistic	Resisted sprints	VJ-HZ
Intensity	30–70% 1RM	High	High
Volume	2–3 sets 4–8 reps	10 m 5–8 reps	2–3 sets 8–10 reps
Frequency		2–3 sessions·wk^{-1}	
Sport-specific training		5–6 sessions·wk^{-1}	
Official matches		1–2 official matches·wk^{-1}	
Lockdown period			
Exercise type	BM		VJ-HZ
Intensity	Low		Moderate
Volume	2–3 sets 10–12 reps		2–3 sets 6–8 reps
Frequency		2–3 sessions·wk^{-1}	

*BW = body mass; HIIT = high-intensity interval training; HZ = horizontal jumps; Reps = repetitions; RST = resisted sprint training; VJ = vertical jumps; wk = week.

quarantine. By signing a professional contract with the club, all players provided individual written informed consent for data collection and study participation. All procedures were approved by the Catholic University of Murcia (UCAM) Ethics Committee and were conducted according to the Declaration of Helsinki.

Procedures

Sprint Acceleration Test. Two pairs of photocells (WITTY System, Microgate, Bolzano, Italy) were positioned at the starting line and at 10 m. Players started from a standing position, 0.3 m behind the starting line, and performed a maximal all-out linear sprint twice, with a 1-minute rest (intraclass correlation coefficient [ICC] = 0.82, coefficient of variation [CV]: = 3.9%). Players started the test when ready, with no investigator's signal. Given the short distance (i.e., 10 m) assessed, the test could be considered to evaluate acceleration capabilities because players did not achieve maximum sprinting velocity. All athletes performed the test using the regular futsal shoes and on a wooden surface. The fastest time was retained for analysis.

Horizontal Jump Test. Athletes stood with their feet shoulder-width apart behind the starting line and the arms at the side of the body. They were instructed to jump as far as possible in the horizontal direction. A countermovement with arm swing was allowed. Players performed a maximal effort 3 times with a 1-minute rest (ICC: = 0.91, CV: = 3.7%). Athletes were required to land with both feet simultaneously, and in case they fell forward or backward, the trial was considered invalid and repeated. The distance between the starting point and the heel of the rear foot measured by a tape to the nearest 1 cm was considered. The longer distance was recorded for analysis.

Vertical Jump Test. Countermovement jump was used to determine the vertical jump ability. Athletes were required to perform a downward movement, followed by a complete, rapid extension of the lower limbs. The depth of the countermovement was self-selected to avoid changes in jumping coordination. The hands were placed on the hips throughout the whole movement, and athletes were directed to jump as high as possible and land close to the take-off point. They executed 3 maximal trials with 1-minute rest (ICC: = 0.94, CV: = 6.0%). The CMJ was performed on a Kistler 9286BA portable force platform (Kistler Group, Winterthur, Switzerland), and the data were exported and analyzed with the software ForceDecks (Vald Performance, Brisbane, Australia) and processed using Python (v.3.8.3). Jump height and multiple kinetic variables (e.g., impulse, peak power, peak force, and velocity or rate of force development [RFD]) (8) from the best jump trial (according to highest jump height) were retained for analysis.

Body Composition. All the assessments were completed by the same experienced evaluator (nutritionist), who had ISAK certification, in accordance with ISAK's international standards (28). Players were required to be on a fasted state, to avoid caffeine and alcohol consumption for at least 8 hours before the procedure, and to wear only the team's training shorts. Body mass was assessed using a Tanita HD-313 scale (Tanita Corporation, Tokyo, Japan) with a 150 kg capacity and accuracy to the nearest 0.1 kg. Eight skinfold measurements were taken with a Harpenden caliper (Baty International, RH15 9LB, England; width of 80 mm and accuracy to 0.2 mm) from the following defined ISAK sites: triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, frontal thigh, and medial calf. Percentage of body fat was estimated according to Yuhasz's equation (31) and muscle mass (kg) to Matiegka's equation (9).

Statistical Analyses

Data are presented as mean ± *SD*. Statistical analysis was performed using the Jamovi statistical package (2020; version 1.2). Normality was checked with the Shapiro-Wilk test. A paired sample *t*-test (parametric variables) or a Wilcoxon test (non-parametric variables) was used to detect differences between pre-post measurements. Cohen's effect sizes (ESs) with 95% confidence intervals (95% CIs) were computed to determine the magnitude of every paired comparison and classified as follows: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), and very large (>2.0–4.0) (4). Significance level was set at $p \leq 0.05$.

Results

Figures 1 and 2 display the group and individual data for sprint and horizontal jump performances, respectively. Considering sprint, a significant and large decrease in performance was observed ($p = 0.004$; ES = 1.31). By contrast, small and non-significant pre-post differences were found in horizontal jump ($p = 0.243$; ES = −0.39).

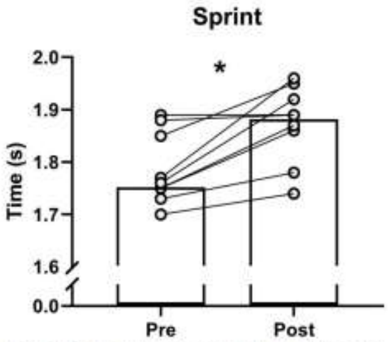

Figure 1. Prequarantine and postquarantine sprint time data. Bars represent mean values, and symbols and lines represent individual changes. $^{*}p < 0.05$.

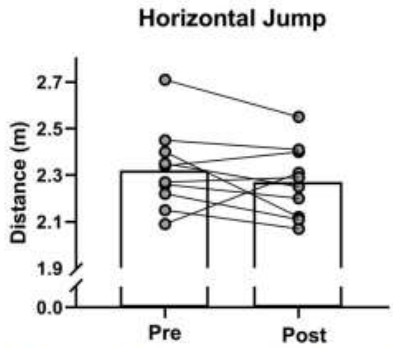

Figure 2. Prequarantine and postquarantine horizontal jump distance data. Bars represent mean values, and symbols and lines represent individual changes.

Figure 3 presents the group and individual data for vertical jump performance, and Table 2 depicts the data for selected CMJ kinetic variables. Moderate and nonsignificant pre-post differences were found in vertical jump height (p = 0.076; ES = −0.63). In the CMJ eccentric ("downward") phase, significant decreases were observed in deceleration impulse (p = 0.006; ES = −1.13), RFD (p = 0.041; ES = −0.75), peak velocity (p = 0.006; ES = 1.12) and peak power (p = 0.004; ES = 1.23). Nonsignificant, trivial or small declines were detected in all concentric ("upward") phase variables and landing RFD to peak force (p = 0.129; ES = −0.52). Moderate significant differences were found in peak force (p = 0.050; ES = −0.70) during the landing phase.

Table 3 depicts the data for the body composition variables pre-post confinement. Trivial and nonsignificant differences were obtained in total body mass (p = 0.992; ES = 0.00), fat mass (p = 0.947; ES = −0.02), and muscle mass (p = 0.734; ES = −0.11).

Discussion

To the best of our knowledge, this is the first study to investigate the effects of 70 days of reduced training caused by the COVID-19 on speed-power–related performance and body composition in elite futsal players. Notably, the main findings indicated that (a) a significant impairment in short sprint (i.e., acceleration) performance was found after the quarantine period; (b) vertical jump height was not significantly affected during home confinement but significant differences were observed in specific eccentric "downward" and landing phase kinetic variables; (c) horizontal jump performance was not significantly affected during lockdown; and (d) players experienced no significant changes in body composition. The present data indicate that long-term reduced training may have a negative effect on acceleration capabilities and alter aspects of neuromuscular performance identified by vertical jump kinetic analysis. Yet, vertical jumping height and horizontal distance can be maintained for prolonged periods (70 days) in professional futsal players by completing training routines based on exercises that can be performed at home, without thorough supervision or the need for additional training equipment.

Considering sprinting acceleration performance, it seems that long-term reduced training (>8 weeks) may affect sprint capabilities of elite futsal athletes. Importantly, in this unusual scenario (i.e., 70 days of home confinement), players were unable to perform any type of high-intensity running actions due to the mandatory lockdown (i.e., spatial constrains), which may have contributed to the observed declines in acceleration ability. These results support previous findings showing impairments in sprint performance after long-term reduced training in soccer players (11,17,25). For example, Koundourakis et al. (17) observed that after a 6-week training cessation (i.e., 2 weeks abstained from any activity and 4 weeks performing only 20–30-minute slow running 3 times per week), the sprint velocity of elite soccer players decreased significantly. Potential factors explaining these adaptations include an insufficient sprinting stimulus (training volume and intensity), changes in muscle fiber type and in cross-sectional area of type II fibers, or alterations of anaerobic enzymatic activity (2,26). From an applied perspective, coaches should be aware that impairments in acceleration ability may be expected after long-term training cessation or reduced training in team-sport players. Thus, for these athletes, returning to training practices after prolonged periods of low volume of high-intensity running and sprint training should focus on progressively

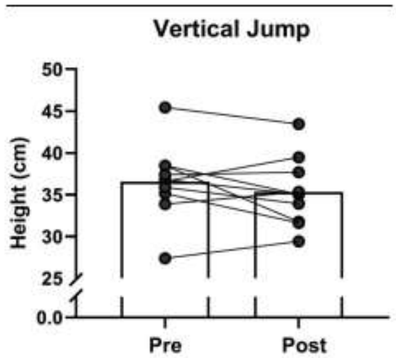

Figure 3. Prequarantine and postquarantine vertical jump height data. Bars represent mean values, and symbols and lines represent individual changes.

Table 2
Comparison of countermovement jump kinetic variables before and after the confinement.*†

Variables	Units	Pre Mean ± *SD*	Post Mean ± *SD*	*p*	Effect size (95% CI)
Jump height	cm	35.78 ± 4.58	34.10 ± 3.54	0.076	−0.63 (−1.30 to 0.06)
Eccentric ("downward") phase					
Decel impulse	$N \cdot s^{-1} \cdot kg^{-1}$	1.36 ± 0.14	1.19 ± 0.16	0.006‡	−1.13 (−1.91 to −0.30)
Peak velocity	$m \cdot s^{-1}$	−1.39 ± 0.14	−1.21 ± 0.17	0.006‡	1.12 (0.30 to 1.90)†
Peak power	$W \cdot kg^{-1}$	−20.85 ± 5.20	−16.40 ± 4.00	0.004‡	1.23 (0.38 to 2.05)†
RFD§	$N \cdot s^{-1} \cdot kg^{-1}$	77.39 ± 23.46	67.82 ± 24.68	0.041‡	−0.75 (−1.44 to −0.02)
Concentric ("upward") phase					
Impulse	$Ns \cdot kg^{-1}$	2.67 ± 0.17	2.61 ± 0.13	0.091	−0.59 (−1.26 to 0.09)
Peak velocity	$m \cdot s^{-1}$	2.78 ± 0.15	2.73 ± 0.13	0.096	−0.58 (−1.24 to 0.10)
Peak power	$W \cdot kg^{-1}$	53.27 ± 6.09	53.48 ± 6.67	0.911	0.03 (−0.58 to 0.65)
Landing phase					
Peak force	$N \cdot kg^{-1}$	97.06 ± 24.92	76.88 ± 18.47	0.050‡	−0.70 (−1.38 to 0.00)
RFD to peak force‖	$N \cdot s^{-1} \cdot kg^{-1}$	3,176 ± 2,965	1948 ± 1,320	0.129	−0.52 (−1.18 to 0.14)

*CI = confidence interval; Decel = deceleration; RFD = rate of force development.
†As eccentric ("downward") phase velocity and power are negative values, the decrease in values for these variables manifests as a positive ES.
‡$p < 0.05$; significant pre-post differences analyzed by a paired sample *t*-test.
§Eccentric RFD: average RFD (Δforce/Δtime) calculated from the start of the eccentric yielding phase (minimum force [time 1]) to the end of eccentric ("downward") phase [time 2].
‖RFD to peak force: average RFD calculated from landing [time 1] to landing peak force [time 2]. Impulse, force, RFD, and power variables are expressed relative to body mass.

developing the speed-related qualities, from the early acceleration to maximum velocity phases.

Of note, horizontal and vertical jumping distance and height, respectively, were not influenced by the quarantine, which is in line with previous studies investigating long-term training cessation (i.e., > 4 weeks) in team-sports (8,19). In a sample of high-level handball players, Marques et al. (19) reported that a period of 7 weeks of reduced training did not negatively affect CMJ height. By contrast, an investigation into elite soccer players revealed significant decreases in CMJ and squat jump after a transition period of 6 weeks (17). These results might be explained by possible changes in fiber type morphology (2) due to the complete absence of plyometric training during the period (note that in the study by Koundorakis et al. (17) players performed only slow-running activities for 20–30-minute, 2 to 3 times per week). Regarding our study, it is important to highlight that (a) futsal players performed a semistructured maintenance training program comprising vertical and horizontal jumps throughout the lockdown in an attempt to minimize potential declines in neuromuscular performance (15) and (b) individual responses differed among players (as seen in Figures 2 and 3), which suggests that tailored training strategies may be necessary. Nevertheless, in applied terms, jumping ability (i.e., as determined by jump height) seems to be maintained during prolonged periods of reduced training. Therefore, coaches are encouraged to prescribe different types of vertical and horizontal jump exercises during long-term reduced training periods, keeping in mind that individual responses may vary among players.

An interesting and novel finding in this study was that a thorough analysis of CMJ kinetics revealed that eccentric (i.e., deceleration impulse, peak velocity and power, and RFD) and landing variables (i.e., peak force) were significantly affected by the reduced training period, in line with a recent study conducted with professional soccer players (8). Specifically, Cohen et al. (8) found that a long-term reduced training (i.e., players completed an isolated resistance and aerobic interval training) during the quarantine was successful in maintaining jump height, peak concentric power, and several other kinetic variables, but not specific eccentric and landing force, RFD, and velocity metrics. This suggests potential alterations on stretch-shortening cycle mechanisms, muscle-tendon properties (8), or movement strategies used by the athletes that may impair, for instance, their ability to rapidly and efficiently decelerate (i.e., high eccentric loading). Noteworthy, another investigation (11) demonstrated a significant decrease in CMJ (i.e., an eccentric-concentric action) but not in squat jump (i.e., concentric-only movement) height after the quarantine in soccer players, which further supports that eccentric and landing qualities are more sensitive and harder to retain during extended periods of reduced training. Still, further studies are necessary to identify the precise mechanisms explaining this phenomenon and to allow providing more robust recommendations for returning to competition practices, after extended absences off-court.

Regarding body composition, it is well established that a reduction in physical activity levels diminishes energy expenditure (13). Therefore, decreasing energy intake may be necessary to

Table 3
Comparison of body composition variables before and after the confinement.*

Variables	Pre Mean ± *SD*	Post Mean ± *SD*	Mean diff (%)	*p*	Effect size (95% CI)
Body composition					
Body mass (kg)	76.0 ± 6.6	76.0 ± 6.7	0.1 ± 4.2	0.992	0.00 (−0.61; 0.62)
Fat mass (%)	9.29 ± 1.46	9.28 ± 1.70	−0.3 ± 6.0	0.947	−0.02 (−0.64; 0.59)
Muscle mass (kg)	50.1 ± 1.56	50.0 ± 1.48	−0.1 ± 1.5	0.734	−0.11 (−0.73; 0.51)

*CI = confidence intervals.

avoid undesirable changes in body composition (e.g., increases in body fat). Remarkably, the mandatory confinement seemed not to affect players' body composition (i.e., total body mass, body fat percentage, and muscular mass). The results of this research are not supported by other studies investigating the effects of prolonged training cessation (11,17,24). In this context, Ormsbee et al. (24) noted that swimmers' body composition and metabolism were adversely affected after more than a month of training cessation that usually occurs after the last competition of the season. Our results may be explained by the fact that futsal players had continuous contact with the team's nutritionist, who prepared individualized dietary plans every 2 weeks according to player's needs, and the caloric intake was reduced during the lockdown when compared with the in-season. Furthermore, players were highly motivated to follow the nutritional guidelines imposed because shortly after the confinement they had to play the Spanish League Playoffs; thus, they were expected to be prepared to return to a decisive phase of the competition within few weeks after the lockdown. This contrasts with other studies (17,24) in which detraining comprised unstructured light-moderate physical exercise (mainly running-based activities, e.g., 20–30-minute jogging, 2–3 times per week), was part of the transition phase, and was followed by a specific pre-season period with limited competition demands.

This study is limited by its small sample size. Nevertheless, it is important to note that the futsal team (a UEFA Futsal Champions League finalist) was composed of only 12 athletes, from which 10 were tested prelockdown and postlockdown, representing more than 83% of the team's players. A second limitation is related to the difficulty of the strength and conditioning coaches to (remotely) control the training sessions during the lockdown that may have affected individual responses. Finally, more tests investigating players' neuromuscular performance (i.e., change of direction ability, unilateral/bilateral drop jumps, and maximal eccentric/concentric strength) could allow to better describe the effects of the COVID-19 home confinement on physical performance.

In summary, a detrimental effect of the lockdown was found for sprint performance and specific CMJ kinetic eccentric and landing phase variables in elite futsal athletes. Nevertheless, vertical jump height, horizontal jumping distance, and body composition were not affected. The inclusion of "regular" unloaded lower-body exercises performed at home, without thorough supervision may conceivably explain why athletes were able to maintain their concentric jump performance (but not acceleration ability and underlying neuromuscular qualities identified in the eccentric and landing phases of the CMJ) after the 70 days of reduced training. Coaches and sport scientists should consider the present findings when planning the specific training approaches after long-term reduced training periods.

Practical Applications

Long-term reduced training caused by home confinement had a large negative effect on the acceleration performance of elite futsal players, most probably due to the lack of an appropriate sprint training stimulus. By contrast, as players were able to perform jump-type exercises at home, horizontal jump distance and vertical jump height were not significantly impaired (although moderate ESs were found for the latter). Nevertheless, it is important to highlight that different variables, specifically in the eccentric and landing phases, were found to be significantly affected by the prolonged reduced training period. This finding highlights that implementing a thorough analysis of players' CMJ jump-land kinetics may reveal detraining-related neuromuscular strategy changes that are not expressed in vertical jump height declines, an approach previously shown to be of value in detecting neuromuscular fatigue (7,10). In addition, no changes were found in body composition, emphasizing the importance of having players follow individual dietary plans during prolonged periods of decreased training loads. From an applied perspective, sprinting acceleration and deceleration (i.e., eccentric biased) training strategies should be prioritized when returning to regular training practices to counteract the negative effects caused by long-term reduced training. Moreover, considering players' individual responses, it seems that a low (but frequent) volume of jumping-based exercises (2–3 sets of 6–8 repetitions of vertical and horizontal, unilateral and bilateral jumps, 2 sessions per week) may be sufficient to avoid impairments in jumping capacity (i.e., as determined by jump height) during long-term reduced training periods (i.e., 70 days) in elite male futsal players. However, practitioners should take into account that, as suggested by the significant CMJ kinetic changes, important alterations may still have occurred, which could potentially influence other performance-related and injury-related aspects (e.g., deceleration ability or muscle-tendon properties).

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APPENDIX 9. Study 9: INJURY RATES FOLLOWING THE COVID-19 LOCKDOWN: A CASE STUDY FROM AN UEFA FUTSAL CHAMPIONS LEAGUE FINALISTLIST OF APPENDICES

Reference:

Spyrou, K., Alcaraz, P. E., Marín-Cascales, E., Herrero-Carrasco, R., Pereira, L. A., Loturco, I., & Freitas, T. T. (2022). Injury rates following the COVID-19 lockdown: A case study from an UEFA futsal champions league finalist. Apunts Sports Medicine, 57(213), 100377.

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ORIGINAL ARTICLE

Injury rates following the COVID-19 lockdown: A case study from an UEFA futsal champions league finalist

Konstantinos Spyrou[a,b,c,*], Pedro E. Alcaraz[a,c], Elena Marín-Cascales[c], Rubén Herrero-Carrasco[d], Lucas A. Pereira[e,f], Irineu Loturco[e,f,g], Tomás T. Freitas[a,b,c,e]

[a] *UCAM Research Center for High Performance Sport, Catholic University of Murcia, Murcia, Spain*
[b] *Faculty of Sport Sciences, Catholic University of Murcia, Murcia, Spain*
[c] *Strength & Conditioning Society, Rome, Italy*
[d] *Research Group Murcia Soccer Federation, Murcia, Spain*
[e] *NAR – Nucleus of High Performance in Sport, São Paulo, Brazil*
[f] *Department of Human Movement Sciences, Federal University of São Paulo, São Paulo, Brazil*
[g] *Department of Sport and Exercise, University of South Wales, Pontypridd, Wales*

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Five-a-side soccer;
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Injury characteristics

Abstract
Introduction: Recently, a pandemic disease (i.e., COVID-19) arose complicated conditions for players, clubs, and sports competitions. Most European countries postponed or canceled their respective leagues as players were forced into a long-term lockdown. This case study presents and compares the absolute and relative non-contact lower-limb injury rates and characteristics before and after the lockdown from a Finalist of the UEFA Futsal Champion League.
Material and methods: Thirteen elite futsal players (age: 27 ± 2.8 years old; body mass: 76 ± 5.4 kg; height: 1.79 ± 0.1 m; body fat: 9 ± 1.6%) participated in this study. Injury severity, location, type, and mechanism were recorded. Data from the 6 weeks pre- and post-lockdown were collected, and injury rates were expressed per 1,000 training and match hours.
Results: Chi-Square tests revealed a significant difference ($p = 0.039$) in the distribution of the number of injuries between the two moments. No overuse and non-contact injuries were observed during the 6 weeks before the lockdown. Nevertheless, 38% (i.e., 5) of the players suffered minimal severity (i.e., ≤ 3 days of court absence) overuse injuries in the hip/groin and thigh muscles post-home-confinement.
Conclusions: Elite male futsal players sustained a substantially higher number of lower-body non-contact injuries after the lockdown. Practitioners should implement a thorough analysis of players' neuromuscular qualities and fatigue to identify individual training and recovery needs and, thus, prescribe more tailored injury-reduction programs.

* **Corresponding author:** Konstantinos Spyrou, UCAM Research Center for High Performance Sport, Catholic University of Murcia, Campus de los Jerónimos, 30107, Guadalupe, Murcia, Spain
E-mail address: kspyrou@ucam.edu (K. Spyrou).

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Introduction

In 2020, a pandemic disease (i.e., COVID-19) arose complicated circumstances for athletes, clubs, and sports competitions.[1] Most European countries postponed or canceled their respective championships as players were forced into a long-term lockdown during the in-season period (March-May). This unprecedented situation led National leagues and federations to adjust the competitive calendars to allow finishing the competitions in due time. For example, the *Liga Nacional de Fútbol Sala* (LNFS; 1st Division of Spain) determined that the league's first play-off game was to be played within few weeks after a ~60-day lockdown, a period with reduced training. Therefore, several recommendations were provided by the scientific community to tackle the potential detraining effects on physical performance and minimize the risk of injury when returning-to-competition after the lockdown.[2–4]

Futsal is a high-intensity intermittent team-sport, in which players are exposed to high metabolic and neuromechanical stress during match-play.[5] Regarding injury characteristics, a recent meta-analysis [6] found that male players displayed: 1) an overall injury incidence rate of 6.8 injuries/1000-h and; 2) an incidence rate of 44.9 injuries/1000-h during match-play. Likewise, it was found that professional players from the 1st and 2nd LNFS sustained ~10 injuries/1000-h of training and ~60 injuries/1000-h of competition during the pre-season and that most injuries affected the lower-limbs (i.e., 92.1%).[7] Nevertheless, all previously published data are based on the analysis of "regular" competitive scenarios (i.e., no in-season breaks due to a lockdown) and no investigation has reported the effects of the unique situation caused by COVID-19 on injury occurrence in elite futsal.

Therefore, the aims of this case study were to examine and compare the absolute and relative lower-limb injury rates 6 weeks pre- and post-lockdown. Due to the extensive period of reduced training, we hypothesized that the relative number of non-contact injuries would be greater after the season intermission (i.e., post-lockdown).

Materials and methods

Study design

A pre-post retrospective cohort case study design was used. Due to the COVID-19 pandemic, all futsal activities (i.e., training and competition) were canceled on March 14th, 2020. The pre-lockdown injury profile was compiled from January 27th, 2020 to March 13th, 2020. During this period, players completed 53.3 ± 5.4 h of training and 6 matches. The post-lockdown injuries were collected from May 12th, 2020 to June 24th, 2020 (last league play-off game). Players completed 52.9 ± 2.8 h of training and 5 matches. These time periods were selected for further analysis to guarantee similar exposure time. Only non-contact lower-body injuries were analyzed (injuries caused by external factors, such as contact with other players, were disregarded). In the present study, an injury was defined as any physical complaint sustained by a player that resulted from a match or training, irrespective of need for medical attention or time loss from activities.[8] The team's physician was responsible for the evaluation and recording of injuries according to the consensus statement of injuries in soccer,[8] previously used in futsal.[7]

Participants

Thirteen elite male futsal players (age: 27 ± 2.8 years; body mass: 76 ± 5.4 kg; height: 1.79 ± 0.1 m; body fat: 9 ± 1.6%), competing in LNFS and Finalists of the UEFA Futsal Champions League were monitored. By signing a professional contract with the club, all players provided individual consent for data collection and study participation. All procedures were approved by the Local Human Subjects Ethics Committee and conducted according to the Declaration of Helsinki.

Procedures

Injuries were classified according to: 1) severity; 2) location; 3) type; and 4) mechanism. No injury reoccurrence was observed; hence, this condition was excluded. Injury severity considered the time period from the day of the injury to the date of the player's return to full participation with the team and was classified as: minimal ($\leq$ 3 days); mild (4 – 7 days); moderate (8 – 28 days); and severe (> 28 days). If the player sustained an injury but was available the following day, the incident was recorded as a time loss of zero-day severity. Injury location and type were classified and divided into six (i.e., hip-groin, thigh, knee, lower leg-Achilles tendon, ankle, foot-toe) and four categories (i.e., fractures and bone stress, joint [non-bone] and ligament, muscle and tendon, contusions), respectively.[8] Injury mechanisms were classified as overuse (i.e., unidentifiable event, usually due to repeated micro-traumas) or traumatic (i.e., specific identifiable occurrence).[8]

Time exposure for each player considered the total time spent in training and competition. Team talks and video tactical sessions, meetings with sport psychologists and nutritionists, and personal activities undertaken away from the team's staff were not included. Injury rates were expressed per 1,000 hours of training and match combined.

Statistical analysis

Statistical analysis was performed using SPSS Statistics, version 22.0 (SPSS, Inc., Chicago, IL). Descriptive data of absolute and relative number of injured athletes pre- and post-lockdown were reported. The distribution in the number of injuries between both periods of analysis was compared through the Chi-Square test and the z-test and the 95%

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confidence intervals (95% CIs) were computed. The statistical significance was set as $p \leq 0.05$.

Results

Tables 1 and 2 report the pre- and post-lockdown lower-limb injury rates and characteristics. No lower-limb overuse injuries were observed pre-lockdown. Nevertheless, 38% (i.e., 5) of players suffered from non-contact overuse injuries after the lockdown in hip-groin and tight muscles, all sustained during training. Chi-Square tests revealed a significant difference in the distribution of the number of injuries between the two moments ($p = 0.039$).

Discussion

This case study identified a greater number of non-contact lower-body injuries (incidence of 7.73⊠1000⊠h^{-1} [95% CI: 2.19–13.27]) after the lockdown in an elite futsal team. Specifically, ~40% of the players (i.e., 5) suffered minimal severity injuries (i.e., ≤ 3 days of court absence) during the 6 weeks following home-confinement. Conversely, no injuries were registered before the lockdown considering the same exposure time.

In general terms, overuse injuries are more common during the pre-season when compared to the rest of season.[9,10] This has been suggested to occur due to inadequate recovery and/or inappropriate loading during the first weeks of preparation following reduced training periods (i.e., transition period).[10] Considering the context of the present study, the post-lockdown period may be considered as a "mini preparatory phase" with the distinctive aspect that players returned from a home-confinement characterized by a sudden decrease in the number and frequency of high-intensity motor actions, especially those involving the stretch-shortening cycle (as compared to the in-season).[11] Moreover, players had only a few weeks to prepare for a highly demanding official play-off league match. Therefore, we speculate that some athletes were not able to cope with the high physical and technical demands of futsal training and competition; hence, the greater number of overuse injuries.[12]

Previous studies have shown the detrimental effects of the COVID-19 lockdown on neuromuscular performance in elite team-sports athletes.[13,14] In particular, a recent study [11] using the same sample of elite male futsal players revealed that home-confinement resulted in a significant impairment in 10-m sprint performance. Of interest, vertical jump height remained unaltered, although several kinetic variables (i.e., eccentric peak velocity and power, rate of force development, and landing peak force) were affected post-lockdown, despite players performing a maintenance training program while confined, as described elsewhere.[11] Noteworthy, the main differences were obtained for the eccentric and landing phases, suggesting that alterations on muscle-tendon properties [13] or stretch-shortening cycle mechanisms may have occurred during this period. To some extent, these important modifications can justify the higher number of injuries post-lockdown. These changes in neuromuscular function may have affected players' ability to efficiently decelerate and tolerate high eccentric-loading actions, which is highly and frequently required in futsal.[5]

It is important to highlight that futsal is characterized by high-intensity activities such as accelerations, decelerations, and directional changes.[5] The issue here is that, during the lockdown, it was not possible to provide these types of stimuli to the players. In addition, the reduced period of training before competition could have resulted in the higher rates of injuries observed in the post-lockdown period, even considering that the number of matches was greater before the home-confinement (6 official matches *vs* 4 friendly and 1 official). Importantly, due to the reduced sample size and the elite level of the players examined here, the present results should not be generalized. Further retrospective investigations on pre- and post-lockdown injury rates with greater sample sizes and timeframes or involving athletes from different sports and performance levels are warranted.

In summary, a significant increase in non-contact lower-body injuries was observed after the COVID-19 lockdown in elite futsal players. Specifically, when considering an equal exposure time, the injury incidence was 7.73⊠1000⊠h^{-1} (95% CI: 2.19–13.27) after the quarantine, as opposed to no overuse injuries recorded pre-lockdown. Therefore, following long-term training cessation, practitioners are advised to: 1) implement a thorough analysis of players' neuromuscular qualities and fatigue [through vertical jump kinetics, for example [15]], to identify individual necessities and, thus, prescribe more tailored injury-reduction programs; 2) optimize recovery strategies to allow players to better tolerate

Table 2 Injury characteristics post-COVID-19 lockdown.

Post-COVID-19 Injury Characteristics		
Mechanism of injury	Overuse	5
Injury severity	Minimal	5
Injury location lower-limbs	Hip/groin	4 (80%)
	Thigh	1 (20%)
Injury type	Muscle and tendon	5 (100%)

Table 1 Injury indices before and after the COVID-19 lockdown.

	Pre-COVID-19	Post-COVID-19	$p\ \chi^2$
Total Exposure Time (h)	53.3 ± 5.4	52.9 ± 2.8	
Total Injuries	-	5	
Injury Incidence (n•1000 h^{-1})	0	7.73 (95% CI: 2.19–13.27)	0.039

Values presented as mean ± SD.
$p \leq 0.05$; significant pre –post differences analyzed by a Chi-Square test.
h: hours; SD: standard deviation.

the high training and playing demands during congested calendars; and 3) closely monitor external and internal training loads. Finally, sport organizations and federations should consider that players may need longer preparation periods to ensure safer return-to-competition practices after prolonged periods of training cessation or reduced training, and that competitive schedules should be adjusted to protect players' health and maintain optimal levels of performance throughout the competitive period.

Conflicts of interest

The Authors declare that they don't have any conflict of interests.

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