FUTSAL RESEARCH AND CHALLENGES FOR SPORT DEVELOPMENT

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PUBLISHED IN: Frontiers in Psychology

frontiers Research Topics

ISSN 1664-8714
ISBN 978-2-88974-900-3
DOI 10.3389/978-2-88974-900-3

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FUTSAL RESEARCH AND CHALLENGES FOR SPORT DEVELOPMENT

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Citation: Méndez-Domínguez, C., Nakamura, F. Y., Travassos, B., eds. (2022). Futsal Research and Challenges for Sport Development. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88974-900-3

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frontiers in Psychology

EDITORIAL
published: 21 March 2022
doi: 10.3389/fpsyg.2022.856563

Editorial: Futsal Research and Challenges for Sport Development

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Keywords: futsal, performance, learning process, monitoring and testing, player development, coaching (performance)

OPEN ACCESS

Edited by:
Luiz H. Palucci Vieira, São Paulo State University, Brazil

Reviewed by:
Zeki Akyildiz, Gazi University, Turkey
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *17 January 2022*
Accepted: *11 February 2022*
Published: *21 March 2022*

Citation:
Méndez-Dominguez C, Nakamura FY and Travassos B (2022) Editorial: Futsal Research and Challenges for Sport Development. Front. Psychol. 13:856563. doi: 10.3389/fpsyg.2022.856563

Editorial on the Research Topic

Futsal Research and Challenges for Sport Development

Futsal is an indoor team sport that is played worldwide by men and women, boys and girls, in both professional and amateur leagues but also in schools and most of futsal academies as a strategy to improve players' development (Barbero-Alvarez et al., 2008). Over the last 15 years its popularity increased a lot, which may be confirmed by the rising number of male and female participants, and it is being promoted and recognized by FIFA and UEFA, with the organization of new youth and senior female European Competitions (Lago-Fuentes et al., 2020). Although futsal is one of the sports with the greatest increase in the number of practitioners and social recognition worldwide, both recreationally and competitively, in recent years, such development has not been accompanied by a similar number of investigations that support the intervention of the coach. Thus, in this Research Topic we invited the submission of manuscripts that promoted the transfer of theoretical research and contribute with practical implications for the development of futsal.

From the overall of the twenty-six manuscripts submitted and twenty-two accepted, nine (40%) were led by Spanish authors, and seven (32%) by Brazilian authors. The other submissions came from Portugal and Taiwan (9% each), and from Croatia and Japan (4.5% each). Of the total of twenty-two accepted manuscripts, fourteen were focused on the physical and physiological futsal demands, in addition to 1 systematic review that includes common aspects; another 2 aimed to technical-tactical aspects, 2 regarding different aspects of performance in female futsal players, and another 3 related to psychological and biomechanical aspects.

The most relevant topic in our compilation was related with the characterization of the physical and physiological demands of futsal performance, through the measurement of internal and external load indicators in training and competition. Seven manuscript were focused in external load: (i) Illa, Fernandez, Reche, Carmona, et al., using a Local Positioning System (LPS) [similar technology to a Global Positioning System (GPS), but which only provides players position information relative to a local field or area], carried out an accurate evaluation of the external load demands in competition and training, describing the frequency and distribution throughout the weekly microcycle to find high and very high demand scenarios that coincide with matches, but also with the training session held 2 days before the match; (ii) also using the same system, Fernandez, Reche, Carmona, Serpiello, et al. quantified the most demanding external load scenarios in elite futsal matches, identifying differences between playing positions (defenders, wingers, and pivots) during different time windows, and also between matches, suggesting the importance of contextual variables like conditioning factors of the "requirement degree"; (iii) Silva et al. focused on the external load variables during pre-match warm-up routines, since the tasks in which intensity increases mainly due to the greater number of accelerations and decelerations per minute; (iv) with the main goal of match demands characterization, Ribeiro et al. highlighted the importance of deceleration in order to cope with match situations and master the space-time relationship to gain advantage, which makes the accelerations and decelerations variables the ones discriminating elite futsal players; (v) Sekulic et al. analyzed the importance of the futsal specific capacities and abilities to differentiate performance levels between professional players, and those who are starters and substitutes; and (vi) Garcia-Unanue et al. identified performance differences in favor of elite players compared to non-elite players in sprint and agility tests, although the contractile properties of the lower body was not a determining factor.

The last manuscript of this group analyzed the physical demands of elite futsal referees during competition. Serrano et al. monitored with the Local Positioning System (LPS) the physical demands of elite referees to provide knowledge of the specific activity profile during futsal matches. In line with previous research with futsal players', the characterization of physical demands of futsal referees can be useful to design suitable training programs.

Focusing on the variables of internal load, seven manuscripts were accepted: (i) Dos-Santos et al. measured % HR (Heart Rate) mean and blood Lactate Concentration [La-] and verified that balancing the number of substitutions and the players permanence on the court in both halves promoted similar intensities between the 1st and the 2nd half; (ii) Campos et al. compared the use of two models of High Intensity Interval Training (HIIT) in order to achieve a better training prescription in young futsal players, according to game demands; (iii) Chen et al. measured very short-term heart rate variability records to provide information on training adaptation and autonomic nervous system recovery status in under 20 elite futsal players; (iv) Silva et al. considered the weak correlation between VO_2 estimated from the relationship with HR on a treadmill and VO_2 measured in a simulated futsal game and its poor agreement linked to the futsal intermittent nature; (v) Lu et al. used the perceived measures of training load at the respiratory (respiratory Rating Perceived Exertion RPE) and muscular (muscular Rating Perceived Exertion RPE) levels and cardiac responses in association with training load as useful indicators to understand the young futsal players demands; and (vi) Stochi de Oliveira verified the significant differences established between the competitive and the preparatory periods of the season in the Internal Training Load (ITL) computed through the relationship between the training volume and the Rating Perceived Exertion (RPE). (vii) In line with previous analysis of RPE, Polito et al. analyzed the construct validity of a specific pictorial scale of perceived exertion (GOAL Scale), in which the absence of verbal anchors makes it possible to use it from an inclusive point of view for football, futsal and beach soccer players in different languages and different levels of literacy.

In addition, as a finishing touch to highlight the importance of the biological condition of the players for performance in futsal, the systematic review carried out by Spyrou et al. highlighted the demands of futsal considering different game dimensions such as: internal and external load data, physiological, neuromuscular, and biochemical responses. They also screen the studies to find differences in variables linked to elite and non-elite futsal competitions.

In fact, the description of futsal game demands by considering new technological systems (e.g., tracking systems such as Local Positioning Systems, LPS; video tracking) to measure external and internal load variables in highly competitive environments and during training sessions should be promoted in the future in order to fill the gap between research and practice and promoting more adjusted performance indicators and metrics according to the specific demands of futsal (Ribeiro et al.).

The collection could not miss the offensive and defensive tactical aspects of futsal teams and players by controlling variables associated with the game that lead to the scoring goal or trying to avoid it. Two manuscripts were accepted, one focused on the offensive aspect, while another on the defensive action. Amatria et al. analyzed the construction of offensive sequences, using sequential analysis of delays as diachronic analysis, to identify the game patterns that end with a goal scored in two of the main European futsal leagues (Spanish and Italian); Pizarro et al. analyzed the indirect effects of an intervention program based on a Non-Linear Pedagogy approach (NLP) through the use of Small-Sided and Conditioned Games (SSCG) on Decision-Making (DM) and Executions (Ex) relative to defensive tactical behaviors carried out by young futsal players.

Although the low number of studies submitted in this field, further research should be developed focused on the technical-tactical aspects of the match due it is a decisive aspect of performance (Méndez et al., 2019), and the one that tends to occupy more workload in futsal training. In addition, further studies that combine physiological and technical-tactical variables are required in order to further contextualize the specific game demands of futsal, as it occurs over the match and following the coaches' perspectives. As previously mentioned, the use of new technological systems (e.g., tracking systems such as Local Positioning Systems, LPS; video tracking) to capture positional data of players and teams should be considered to access to spatial-temporal relations between players and teams that sustain specificities of the futsal match in different game environments (Travassos et al., 2013) and in different levels of practice (Travassos et al., 2018).

The inclusion of elite female futsal players in the research studies was an excellent new as a distinctive feature within this Research Topic. First, Cejudo et al. determined the lower extremities joints Range Of Motion (ROM) profile in futsal players by sex, position, competitive level and bilaterality, listing the possible differences between female players with their male counterparts and the implications at the level of physical performance. Second, Queiroga et al. aimed to characterize the age of onset of training, age at menarche, menstrual periodicity, and performance perception during the menstrual cycle, and examined the impact of these reproductive variables on body composition, morphology (somatotype), and body weight satisfaction in Brazilian elite futsal players.

Research developed with female futsal players should be encouraged in order to better characterize it's specificities, uncovering the match demands and improving coaches' practice.

Regarding injuries and mechanical aspects of performance, Rúiz-Pérez et al. applied a supervised Machine Learning techniques to predict Lower Extremity non-contact Soft Tissue (LE-ST) injuries, allowing better identification of elite futsal players at higher risk. Finally Ismail et al. investigated the possible influence of forefoot bending stiffness property of three commercial futsal shoes on change of direction run resultant performance.

Further development of epidemiological studies developed longitudinally and in different levels of practice and sex are required to improve the strategies for the evolution and improvement of players' capacities and injury prevention.

Finally, only one study considered the analysis of psychological aspects in futsal. Brandão et al. used the exploratory Bi-factorial model (BI-ESEM) to evaluate the list of stressors in elite futsal through a self-report instrument, where they tried to know the impact of stressful situations at the level of practical implications for psychological intervention and for improvement of player's life.

Regarding psychological aspects that characterizes and determines performance of futsal players, limited knowledge exists related with this sub-discipline that sustain players' and teams' performance. For sure, it will be a hot topic for the future with great impact in practice.

In light of the great number of high-quality manuscripts published, this special issue has made an important contribution to the development of knowledge in futsal. For the next years, we expect that the current research could be the basis to improve the understanding about physical, technical and tactical game demands, but also to sustain the development of new research that addresses practical implications, particularly related with coaching, pedagogy, talent development, performance analysis, motion analysis, and psychological intervention.

AUTHOR CONTRIBUTIONS

All authors have contributed to the preface, summary and epilog of this editorial article and to its subsequent revision. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

Heartfelt thanks to all the authors and reviewers of the 22 manuscripts in the collection for having contributed with dedication and enthusiasm to the promotion of futsal.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 24 July 2020
doi: 10.3389/fpsyg.2020.01709

Check for updates

Activity Profile and Physical Performance of Match Play in Elite Futsal Players

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Edited by:
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Specialty section:
This article was submitted to
Movement Science and Sport
Psychology,
a section of the journal
Frontiers in Psychology

Received: 20 May 2020
Accepted: 22 June 2020
Published: 24 July 2020

Citation:
Ribeiro JN, Gonçalves B,
Coutinho D, Brito J, Sampaio J and
Travassos B (2020) Activity Profile
and Physical Performance of Match
Play in Elite Futsal Players.
Front. Psychol. 11:1709.
doi: 10.3389/fpsyg.2020.01709

Understanding the physical demands of futsal requires a precise quantification of the players' activities during match play. This study aimed to (1) describe external load, identifying the differences between the first and second halves in official futsal matches; (2) identify the most important external workload metrics to profile the players; and (3) identify the collinearity between variables in the analysis of physical performance of futsal players. Match external load data were collected from male players (n = 28) in six games of the Final Eight of the Portuguese Futsal Cup 2018. The players increased the distance covered per minute at 12–18 km/h in the second half ($p < 0.01$). Dynamic stress load also increased in the second half ($p = 0.01$). The variables that best predicted the physical profile of each player were decelerations (predictor importance, PI = 1), walking (PI = 1), sprinting (PI = 1), jogging (PI = 0.997), total distance covered per minute (PI = 0.992), and metabolic power (PI = 0.989). Decelerations showed the highest association with the clusters levels ($p < 0.001$; PI = 1); this suggests decelerations as a potential candidate for best analyzing the physical load of futsal players. Overall, the data from this exploratory study suggest that distance covered per minute (m/min), number of sprints (>18 km/h), decelerations (greater than-2 m/s), and metabolic power (W/kg) are the variables that most discriminate the load intensity of elite futsal players.

Keywords: team sports, tracking, physical demands, competition, monitoring

INTRODUCTION

The improvement on technological capability to collect and analyze data has increased the knowledge about load and physical demands of team sports and helps to improve training programs, optimizing performance and reducing the likelihood of injury on top-level players (Fox et al., 2017; Vanrenterghem et al., 2017). Its importance has been recently reinforced, since FIFA has approved the use of specific microsensors and wearable devices in official soccer and futsal matches, opening new perspectives for the understanding of players' physical performance during competitive scenarios (Roell et al., 2018).

To better perceive the load that players experience during a match, internal load (IL), and external load (EL) should be measured and characterized (Buchheit, 2014; Fox et al., 2017; Clemente et al., 2019). While IL describes the physiological effects of training on the athlete, EL describes the physical demands of training through measures derived from position data, and/or inertial measurement units (IMUs; Gonçalves et al., 2017; Impellizzeri et al., 2019). Actually, the available technology allows establishing individualized performance profiles through the analysis of IL and EL variables and specific algorithms that allow the use of other parameters, like Player Load (PL^{TM}), or Metabolic Power (PM^{TM}; Bourdon et al., 2017; Polglaze and Hoppe, 2019; Reche-Soto et al., 2019).

External load could be classified into three main categories: (a) kinematics, which quantifies overall movement during exercise; (b) mechanical, which describes a player's overall load during exercise; and (c) metabolic, which quantifies overall movement energy expenditure during exercise (Rossi et al., 2018). The parameters can also be expressed in absolute (total match time) or relative (effective playing time) terms. Still, with the great amount of data available to measure physical load, the challenge is to understand the most reliable and relevant variables that should be collected to characterize activity profiles of players during training sessions and matches (Buchheit and Simpson, 2017).

The scientific knowledge about EL and activity profiles of futsal players is still scarce (Beato et al., 2017; Naser et al., 2017; Taylor et al., 2017). To the best of our knowledge, only five studies have investigated physical demands data in elite futsal players (official matches): one in the Spanish Professional Futsal League—analysis of distances covered and heart rate (Barbero-Alvarez et al., 2008); one in Australian futsal players—analysis of match demands between levels of competition (Doğramaci et al., 2015); and three in Brazil—analysis of sprints (Caetano et al., 2015), distances covered (De Oliveira Bueno et al., 2014), and distances covered, maximum speeds, and heat maps of player displacements (de Pádua et al., 2017). Additionally, most of these studies were developed specifically for physical testing or during simulated games and only reported average values of some EL parameters. From this perspective, more research is required that accurately inform about the physical load experienced by players (Akenhead and Nassis, 2016), as well as data that may help to quantify it.

In this sense, the present study aimed to characterize the EL of elite futsal match play. In addition, data were computed to identify the external workload metrics that distinguish different futsal players' profiles. The collinearity between EL variables was also analyzed. We expected to identify different profiles of play according to players' EL, aiming to improve the understanding of match-play demands in futsal.

MATERIALS AND METHODS

Subjects

Twenty-eight elite male futsal players (age: 24.1 ± 3.4 years) from eight futsal teams that participated in the Final Eight of the Portuguese Futsal Cup 2018 (January 2018) accepted to participate in this study. Inclusion criteria were the following: (1) is a field player; (2) did not report any physical limitations or skeletal muscle injury that could affect performance; and (3) played in both halves in each match. All matches were played in the same neutral indoor multisport court. The study protocol followed the guidelines and was approved by the local Ethics Committee of Universidade da Beira Interior (CE-UBI-Pj-2018-029) and conformed to the recommendations of the Declaration of Helsinki.

Design

An observational research was used to measure and analyze the EL of players who participated in the Final Eight of the Portuguese Futsal Cup 2018. Four matches in the quarterfinals and two matches in the semifinals of the competition at least 48 h apart were used for the analysis. According to the official futsal rules, two halves of 20 min of effective time were played.

Methodology

Players' activity was assessed using IMUs with ultra-wideband (UWB) tracking system technology from WIMU PRO^{TM} (Realtrack Systems, Almeria, Spain). The sampling frequency of WIMUs for the positioning system was 18 Hz. The devices were turned on about 10 to 15 min before the warm-up and placed on players with a specific custom neoprene vest located on the middle line between the scapulae at C7 level. The system has six UWB antennas, placed 4 m outside the court, and operates using triangulation between the antennas and the units to derive the X and Y coordinates of each unit. Data from the beginning to the end of the match with the exclusion of halftime and time-outs were analyzed using SPRO Software (Realtrack Systems SL, Almeria, Spain). The accuracy and reliability of these devices have been previously reported and validated (Bastida-Castillo et al., 2019).

From positional data, variables were extracted based on the three main categories of EL identified (Rossi et al., 2018): (a) kinematics; (b) mechanical; and (c) metabolic. See **Table 1** for details of each variable considered. The absolute and the relative (effective playing time - clock time) values of each variable were calculated.

Statistical Analysis

Normality of the data was tested with the Kolmogorov–Smirnov test. Since normal distribution was not found in all situations, we used the Wilcoxon rank test to identify differences between each half. Mean ± standard deviation (SD) for full-match data and median (Md) and interquartile range (IR) for the first and second halves were calculated.

A two-step cluster with log-likelihood as the distance measure and Schwartz's Bayesian criterion was performed to classify athletes according to their performance profiles over the entire match. The analysis was used to classify the players' performance and to identify the variables that maximized group distances. This method differs from traditional clustering techniques by the handling of categorical variables (assuming variables to be independent), automatic selection of the number of clusters, and scalability (Tabachnick et al., 2007). Through an ANOVA test,

TABLE 1 | EL variables recorded in this investigation.

Type	Variable	Sub-variable	Unit	Description
Kinematics	Distance covered (m)	Total	m	Total distance covered in meters
	Relative distance covered (m/min)	Total	m/min	Total distance covered in meters per minute
		Walking	(0–6 km/h) m/min	Total distance covered between 0 and 6 km/h/min
		Jogging	(6.1–12 km/h) m/min	Total distance covered between 6.1 and 12 km/h/min
		Running	(12.1–18 km/h) m/min	Total distance covered between 12.2 and 18 km/h/min
		Sprinting	(18.1–30 km/h) m/min	Total distance covered between 18.1 and 30 km/h/min
	Sprints	Total	SPR/n/min	Frequency > 18 km/h during > 1 s in 1-min window
	Maximum speed (km/h)	Max	$Speed_{AVG}$	Average max speed
Mechanical	Impacts (Imp/min)	Total	IMP/n/min	Total impacts recorded per minute above 5 *g* force
	Accelerations	Total	ACC (>2 m/s^2) n/min	Total positive speed changes per minute
	Decelerations	Total	DEC (> −2 m/s^2) n/min	Total negative speed changes per minute
	Jumps	Total	JUM/n/min 400-ms flight time	Total number of jumps recorded per minute
	Dynamic stress load (a.u.)	Total	DSL/a.u./min	Total of the weighted impacts of magnitude over 2 *g* per minute
	Player load (a.u)	Total	PL/a.u./min	Accumulated accelerometer load in the three axes of movement
Metabolic	Power metabolic (W/kg)	Total	MP/min	Product of speed and energy cost of the activity derived from inclination and acceleration
	High metabolic load distance (W/kg)	Total	HMLD/min	Distance traveled by a player when the metabolic power is >25.5 W/kg (corresponds to a speed greater than 5.5 m/s or 19.8 km/h)

variables were ranked according to the predictor's importance, indicating the relative importance of each predictor in estimating the model (the sum of the values for all predictors on the display is 1). In the functional sense, the predictor importance of each variable provides different weights to support the cluster distribution. A cutoff level of 0.4 was chosen.

Spearman's correlation test was used to verify the collinearity between variables. Data exploration was conducted based on the correlation matrix that is produced with the "corrplot" function in the R programming language. The criteria adopted to categorize magnitudes of correlations (r) were as follows: ≤0.1, trivial; >0.1–0.3, small; >0.3–0.5, moderate; >0.5–0.7, large; >0.7–0.9, very large; and >0.9–1.0, almost perfect (Cohen et al., 2013).

Correlograms were used, with the intensity of the color increasing as the correlation moves further away from zero. Here, the correlation coefficients were overlain on each symbol, with "red" symbols being used to denote a negative coefficient and "blue" symbols used to denote a positive coefficient.

RESULTS

Physical Demands of Futsal

The analysis of absolute kinematic, mechanical, and metabolic variables revealed statistical differences between halves only for MP^{TM} with the first half requiring more energy expended by players than that in the second half (see **Table 2**).

The analysis of relative kinematic, mechanical, and metabolic variables revealed differences between halves for running (12–18 km/h), with the second half revealing higher distance covered than the first half. Also, dynamic stress load (DSL) was higher in the second half than in the first half (see **Table 3**).

Clusters of Physical Profiles of Futsal Players

The cluster analysis classified the players into three distinct groups according to their physical profiles as higher, medium, and lower (**Table 4**), containing 4.5, 84.2, and 11.2% of the cases, respectively. The deceleration per minute (mechanical variable), walking per minute, sprinting per minute, jogging per minute, distance covered per minute, and MP^{TM} per minute were in descending order as variables that most contributed to the discrimination of the physical profiles of players. Deceleration per minute revealed significant differences between all profiles ($p < 0.001$), while the other reported variables only revealed significant differences between higher and medium and between higher and lower profiles ($p < 0.05$). High metabolic load distance (HMLD) was the most homogeneous variable, with a low predictor importance value.

Collinearity Between EL Variables

Figure 1 presents the level of magnitude of correlations between all the variables used in this study. The variables that showed the highest number of associations were distance covered per minute, deceleration per minute, MP per minute, and jogging per minute. In turn, total impacts per minute, PL^{TM} per min, DSL per minute, and number of jumps per minute did not show any type of correlation with others. The only negative correlation was found between MP^{TM} per min and jogging per minute.

TABLE 2 | Descriptive statistics of absolute values observed during the first and second halves.

	Full match M ± SD	First half MD (IR)	Second half MD (IR)	Wilcoxon *W*	*p*
Kinematics					
Total distance covered	3,749 ± 1,123	1,875 (1,179)	1,674 (1,049)	1.37	0.18
Walking (0–6 km/h)	1,645.1 ± 442.9	792.7 (374.4)	759.4 (398.1)	0.72	0.48
Jogging (6–12 km/h)	1,321.5 ± 479.8	674.4 (465.4)	555.7 (547.9)	1.29	0.21
Running (12–18 km/h)	675.3 ± 298.1	328.6 (271.5)	317.5 (237.1)	1.60	0.12
Sprinting (>18 km/h)	134.9 ± 54.1	73.1 (56.8)	54.8 (55.7)	1.20	0.23
Maximum speed (km/h)	20.3 ± 1.7	20.4 (1.7)	20.6 (2.1)	0.33	0.74
Mechanical					
ACC (n/min)	87 ± 49	44 (43)	34 (36)	1.43	0.16
DEC (n/min)	80 ± 32	40 (35)	36 (33)	0.23	0.82
Jumps (n)	9 ± 4	3 (5)	4 (2)	0.33	0.75
Total impacts (n)	501 ± 388	219 (256)	194 (241)	1.33	0.19
Player load (a.u.)	72.1 ± 22.8	36.1 (19.1)	33.9 (14.7)	2.02	0.05
DSL (a.u.)	673.9 ± 247.7	314.9 (221.9)	340.6 (263.7)	−0.27	0.78
Metabolic					
Metabolic power (W/kg)	13.96 ± 3.09	7.9 (2.4)	6.5 (2.4)	3.73	0.00*
HMLD (W/kg)	655.79 ± 313.80	301.7 (252.9)	325.4 (263.7)	−0.95	0.35

**p* < 0.001 significant difference; M, mean; SD, standard deviation; Md, median; and IR, interquartile range.*

DISCUSSION

The aim of the present study was to describe EL of futsal match play and identify the differences between the first and second halves. In addition, data were used to identify the external workload metrics that distinguish different futsal players' profiles. At the end, the collinearity between external workload variables was also analyzed. To the best of our knowledge, this is the first study in official futsal competitions, and consequently, this is the first report on the kinematic, mechanic, and metabolic variables that characterize the physical load of futsal.

Generally, no meaningful differences were detected between halves. It was possible to identify three futsal players' profile, based on the results of the following variables: deceleration per minute, walking per minute, sprinting per minute, jogging per minute, distance covered per minute, and MP^{TM} per minute.

TABLE 3 | Descriptive statistics of relative values observed during the first and second halves.

	Full match M ± SD	First half MD (IR)	Second half MD (IR)	Wilcoxon *W*	*p*
Kinematics					
Distance covered per minute	232 ± 71	216 (55)	229 (86)	−1.42	0.16
Walking per minute (0–6 km/h)	108.3 ± 51.5	92.5 (30.5)	110.8 (54.8)	−1.24	0.22
Jogging per minute (6–12 km/h)	76.5 ± 24.3	79.5 (16.5)	77.9 (17.9)	−0.54	0.59
Running per minute (12–18 km/h)	30.0 ± 19.2	15.7 (26.4)	38.6 (12.3)	−5.13	0.002*
Sprinting per minute (>18 km/h)	8.5 ± 7.9	7.4 (3.8)	7.3 (5.4)	−1.05	0.30
Sprints (n/min)	2 ± 1	2 (2)	2 (2)	0.84	0.41
Mechanical					
ACC (n/min)	5 ± 2	5.2 (2)	5.1 (2)	0.48	0.63
DEC (n/min)	5 ± 2	5 (2)	5 (2)	−0.77	0.44
Jumps (n/min)	0.8 ± 1.1	0.4 (0.5)	0.5 (0.9)	−1.76	0.09
Total impacts (n/min)	35 ± 35.2	29 (22.4)	30 (28.1)	0.00	1.00
Player load (a.u./min)	4.5 ± 2.3	4.1 (1.3)	4.3 (1.8)	−0.93	0.36
DSL (a.u./min)	15.0 ± 8.5	11.2 (13.4)	15.1 (13)	−2.73	0.004*
Metabolic					
Metabolic power per minute	6.9 ± 1.7	0.9 (0.6)	0.9 (0.8)	1.13	0.27
HMLD per minute	22.8 ± 10.6	22.2 (18.3)	23.7 (7.2)	−0.94	0.35

**p* < 0.005 significant difference; M, mean; SD, standard deviation; Md, median; and IR, interquartile range.*

TABLE 4 | Classification of cluster physical profiles of futsal players.

Variables	Higher M ± SD	Medium M ± SD	Lower M ± SD	Sig. (*p*)	PI
Kinematics					
Distance covered per minute	364 ± 180	231 ± 46	185 ± 102	**, ++	0.992
Walking per minute (0–6 km/h)	249.2 ± 120.3	100 ± 29.5	114.7 ± 64.2	**, ++	1
Jogging per minute (6–12 km/h)	82.2 ± 67.3	80.5 ± 13.2	43.9 ± 37.8	+,#	0.997
Running per minute (12–18 km/h)	49.8 ± 53.5	30.8 ± 15.3	16.1 ± 17.6	+	0.825
Sprinting per minute (>18 km/h)	26.7 ± 31.5	8.2 ± 3.18	3.9 ± 3.3	**, ++	1
Sprints (n/min)	3.0 ± 1.0	2.0 ± 1.0	2.0 ± 1.0		0.126
Mechanical					
ACC (n/min)	5 ± 1	6 ± 2	3 ± 2	##	0.979
DEC (n/min)	10 ± 4	5 ± 1	2 ± 2	**, ++, ##	1
No. of jumps (n/min)	1 ± 1.3	0.6 ± 0.6	0.5 ± 0.46		0.376
Total impacts (n/min)	42 ± 27	29 ± 16	75 ± 86	##	0.968
Player load (a.u./min)	4.3 ± 0.7	4.3 ± 1.3	6.2 ± 5.7		0.634
DSL (a.u./min)	20.7 ± 11	14.4 ± 7.9	17.2 ± 11.2		0.312
Metabolic					
Metabolic power per minute	16.9 ± 32.5	1.4 ± 2.6	1 ± 0.6	**, ++	0.989
HMLD per minute	24.8 ± 2.3	22.9 ± 11.2	21.3 ± 7.6		0.077

*M, mean; SD, standard deviation; PI, predictor importance; *p < 0.05 higher with medium; **p < 0.001 higher with medium; +p < 0.05 higher with lower; ++p < 0.001 higher with lower; #p < 0.05 medium with lower; and ##p < 0.001 medium with lower.*

Also, the explorative analysis of the collinearity between EL variables allow us to identify the variables that have substantial impact to describe futsal physical demands in a simple way (Buchheit and Simpson, 2017). Distance covered per minute, deceleration per minute, jogging per minute, and MP^{TM} per minute were the variables that revealed a higher correlation with other variables.

Futsal Game Characterization

In contrast to previous studies (Barbero-Alvarez et al., 2008; De Oliveira Bueno et al., 2014), no significant differences in EL were observed between the first and second halves of futsal matches. It seems to corroborate the most recent results in futsal in which no significant differences between the first and second halves were reported in IL indicators such as lactate and maximum heart rate values (Milioni et al., 2016). Such results relaunch the discussion about the capability of futsal players to maintain or even increase their physical performance during the entire match. The fact that futsal is characterized by unlimited substitutions and the score of the game may remain uncertain until near the end could be decisive for such results.

The comparison between absolute and relative workloads revealed different trends. Despite there being no statistical differences, there was a general decrease in the absolute values during the second half compared to the first half. In contrast, the relative values revealed a general increase in physical load per minute with clear higher values of running and DSL in the second half compared to the first half. These findings highlight the use of relative measures as more accurate information about the players' intensity according to their participation in the game (Barbero-Alvarez et al., 2008; Whitehead et al., 2018). In this sense, it is clear that the ability to perform high-intensity actions remains during the entire match. In line with previous research, the average sprints (maximum speed) and the number of sprints remained stable between halves (Caetano et al., 2015). However, an interesting finding from this research was the higher distance covered per minute when compared to past research (Barbero-Alvarez et al., 2008; De Oliveira Bueno et al., 2014; Doğramaci et al., 2015). In fact, approximately twice more distance was covered per minute, and a higher number of sprints were performed.

The present study showed an average value of maximum speed of 20.3 km/h, with peak values of 22.6 km/h. The average values of peak sprinting speed is lower when compared with the values (23.8 km/h) reported in a previous report (de Pádua et al., 2017). Such results could be justified by a general increase in the work intensity of players in the last years, as well as by potential differences between leagues.

It is commonly accepted that mechanical variables such as accelerations and decelerations are the most important variables to be tracked in futsal, since they refer to a more neuromuscular- and biomechanical-oriented type of load (Buchheit, 2017). As in soccer, in futsal, due to the small space of action, the ability to accelerate and decelerate is considered decisive during critical actions, including changing direction, or rhythm in response to opponents' actions, reaching the ball, and breaking movements to create space and generate or deny goal opportunities (Arruda et al., 2015). As far as we know, only one study reported mechanical and metabolic demands in futsal. However, it was developed with a female team from the Italian second division (Beato et al., 2017). Our results reported higher absolute values of accelerations and decelerations and similar values for metabolic demands in comparison with those of the female team (Beato et al., 2017).

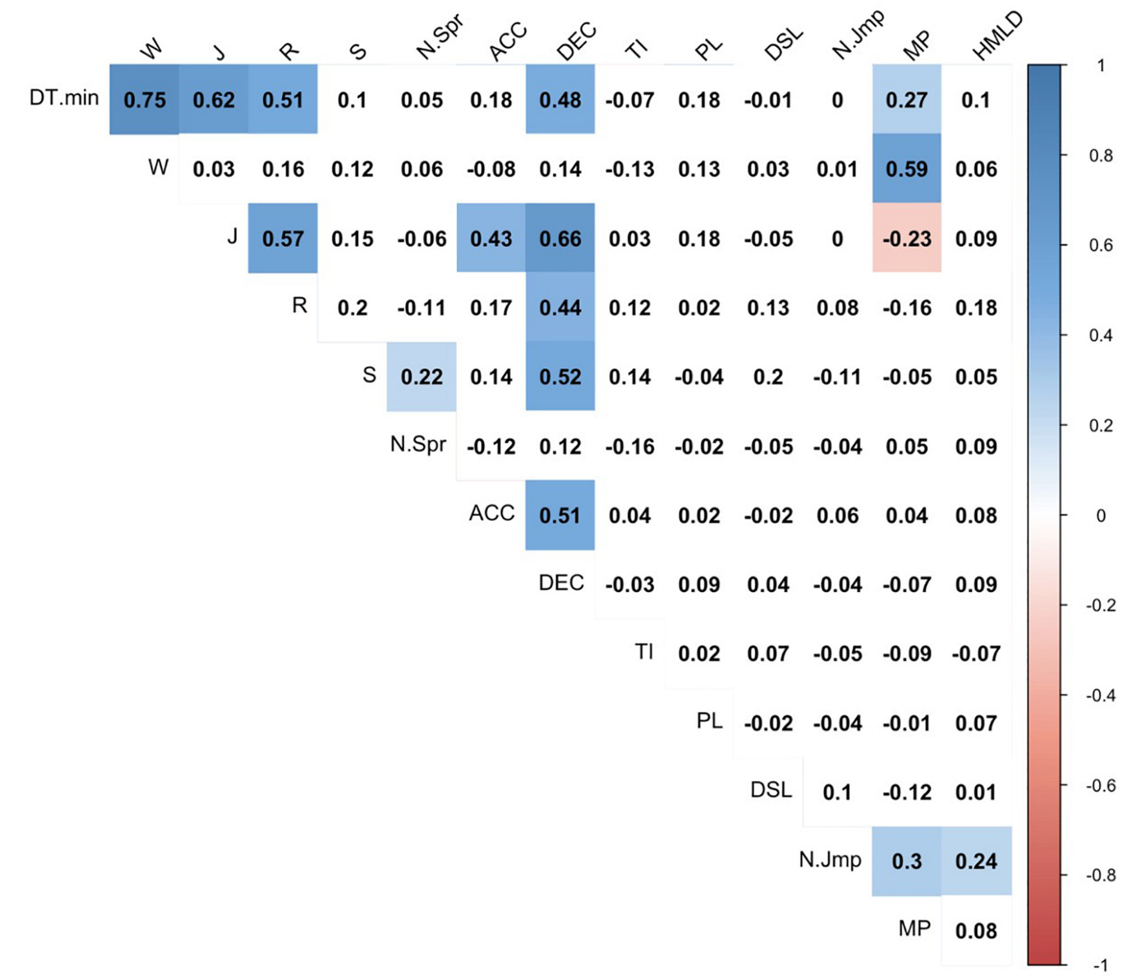

FIGURE 1 | Correlation matrix between EL variables.

Futsal Player's Profile

Futsal is characterized by a set of high-intensity efforts that require players with a high level of athletic performance in a multitude of physical abilities (Caetano et al., 2015; Miloski et al., 2016; Amani-Shalamzari et al., 2019). However, little information and consensus exist about the individual physical profile of futsal players. Identifying the variables that best discriminate the physical profiles of elite futsal players provides important data for the prescription and training periodization, thus highlighting the importance of analyzing and monitoring the physical demands of the match of each player according to their specific profile (Wilke et al., 2019; Rago et al., 2020).

Results of cluster analysis revealed three different groups with higher, medium, and lower levels of physical activity. Most of the players analyzed were classified as medium profile. The physical profiles of elite futsal players were discriminated by one mechanical variable (deceleration per minute), four kinematic variables (distance covered per minute, walking per minute, jogging per minute, and sprinting per minute), and lastly one metabolic variable (MP^{TM} per minute). Indeed, it seems that accelerations and decelerations could be used as reliable measures of different activity profiles of players (Cormack et al., 2014; Arruda et al., 2015). This method may allow grouping of players according to their physical and recovery profiles to understand if a slower or faster recovery can be related to different physical profiles (Wilke et al., 2019). Further research is required to improve the understanding between physical and technical–tactical profiles of play. In line with that, such information can also be used for the evaluation and development of young elite futsal players.

External Workload Metrics: Collinearity Between Variables?

To improve the understanding of each variable and reduce the noise in the analysis, it is essential to simplify the results and improve their interpretation to provide reliable and useful information for coaches and strength-conditioning professionals (Buchheit and Simpson, 2017). For that, collinearity analysis between variables is crucial. Our results revealed that, in general, there were higher correlations between the distance covered per minute (kinematic), deceleration per minute (mechanical), and MP^{TM} per minute (metabolic), and other variables. In addition, the distance covered per minute and jogging per minute were the unique variables that revealed significant correlations with kinematic, mechanical, and metabolic variables. In the end, deceleration per minute revealed a high significant correlation with all kinematic variables except for walking per minute.

Regarding the analysis of kinematic variables, the distance covered per minute revealed significant correlations with walking per minute, jogging per minute, and running per minute, which means that distance covered per minute might be computed to generally represent all running speed thresholds between 0 and 18 km/h. So behind distance covered per minute, it is necessary to monitor distance covered above 18 km/h, in order to characterize all the speed thresholds considered. This evidence is in line with the importance and the need to individualize speed thresholds to provide an insight into players' physical response to training and enable comparisons between player profiles (Rago et al., 2020). Analysis of mechanical variables revealed that deceleration per minute revealed a significant correlation with acceleration per minute. Thus, considering that deceleration per minute was highly associated with almost all kinematic variables, it may suggest that it is a more robust variable for analyzing the physical load of players during futsal training sessions and matches (Cormack et al., 2014). Therefore, it has a large association with the speed threshold of sprinting per minute, which is associated with an increase in heart rate variability, thus being able to play an important role as an indicator of good aerobic fitness (Buchheit, 2014).

The analysis of metabolic variables revealed that only MP^{TM} per minute demonstrated a positive correlation with kinematic variables (distance covered per minute and walking per minute) and a negative correlation with jogging per minute. This evidence suggests that MP^{TM} per minute might be less sensitive to peak demands. Thus, such a variable should be included in the analysis of physical demands of the futsal game as a complement to kinematic and mechanical variables that evaluate high match-play requirements (Polglaze and Hoppe, 2019). However, some caution while using this variable is advised as it does not agree with the literature (Gray et al., 2018).

LIMITATIONS

As a possible limitation of the present investigation, we acknowledge that the sample size and number of matches should be larger in order to increase the power of the results (Lupo and Tessitore, 2016). In turn, the fact that it is a sample made up of elite players allows us to investigate the data of highly competitive demands. Thus, further research should be developed considering the influence of different contextual and situational variables in players' EL, such as the evolution of match status and style of play (Lago-Peñas and Gómez-López, 2014). It would also be interesting to understand the worst-case scenarios (i.e., peak demands) for some EL variables, in order to prepare players for these specific moments of match play.

CONCLUSION AND PRACTICAL APPLICATIONS

Overall, similar values were observed in most of the external variables between the first and second half. Interestingly, while the use of absolute results revealed a trend for a decrease from the first to the second half, in turn, the opposite was revealed when relative variables were analyzed according to the effective time of play of each player. Thus, relative measures to evaluate EL in futsal might be preferable, as it allow comparisons between studies and may also contribute to enhancing the comparison between players' performance in both training sessions and matches.

The analysis of players' profiles revealed that deceleration per minute, walking per minute, sprinting per minute, jogging per minute, distance covered per minute, and MP^{TM} per minute were the variables that best discriminated the profiles between players. Such results could help to better discriminate the individual training needs of each player and thus to adjust the prescription of training sessions. At the end, the explorative analysis of the collinearity between EL variables revealed that the distance covered per minute, deceleration per minute, and MP^{TM} per minute were the variables that revealed a higher correlation with other variables. Specifically, it was observed that distance covered per minute and deceleration per minute discriminate intensity while MP^{TM} per minute discriminated the volume of EL demands. Thus, to ensure a reliable analysis of EL demands in futsal, it is not necessary to measure all variables but rather consider those that better reflect the intensity of match play.

The transfer of this evidence to the training process is very significant; insofar as knowing the intensity of the match and which variables best characterize it, coaches can concretely manipulate and adjust the physical requirement of practice tasks during the microcycle to match demands in order to optimize players' performance and reduce the risk of injury.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions cannot be made available due to the restrictions defined by the participant clubs. Requests to access these datasets should be directed to joaonunorib@gmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by local Ethics Committee of Universidade da Beira Interior (CE-UBI-Pj-2018-029). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JR, JS, and BT contributed to the conception and design of the study. JR, BG, DC, and BT collected the data. BG performed the statistical analysis. JR and BT wrote the manuscript. JS, JB, DC, BG, and BT revised and finalized the manuscript. JR and BT organized the database. All authors contributed to the manuscript revision and read and approved the submitted version.

FUNDING

This work was supported by the National Funding through the Portuguese Foundation for Science and Technology, IP, under the projects UID04045/2020 and SFRH/BD/148271/2019.

ACKNOWLEDGMENTS

The authors would like to express their appreciation for the outstanding efforts and positive attitude of the participants, their coaches, and their clubs.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 15 October 2020
doi: 10.3389/fpsyg.2020.577624

Quantification of an Elite Futsal Team's Microcycle External Load by Using the Repetition of High and Very High Demanding Scenarios

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The main objective of this study was to describe the repetition of external load high-demanding scenarios and very high-demanding scenarios of match play for velocity, distance, and neuromuscular locomotor variables of an elite futsal team. Additionally, we also checked how these high- and very high-demanding scenarios were distributed throughout the microcycle. The most demanding scenario (measured using a rolling average method with a 1-min time window) of match play was measured out of thirteen elite futsal players using a local positioning system in the course of thirteen official matches and six in-season microcycles. A mean of the top three match play observations for each variable and each player were used to determine the most demanding scenario (100%) reference value. Data were reanalyzed to count the number of high-demanding scenarios (80–90% of the individual most demanding scenario) and very high-demanding scenarios (>90% of the individual most demanding scenario). The number of scenarios was analyzed with respect to the number of days prior to the match [match day (MD) minus X] and a bootstrap confidence interval approach was used to assess differences between MD. During a single match, players have to cope with repeated high- and very high-demanding scenarios. Moreover, the training session 2 days prior to the match was the one most similar to the match, surpassing it only in scenarios of locomotor velocity variables, albeit with significantly fewer scenarios of neuromuscular variables. The number of high- and very high-demanding scenarios in the training session prior to the match dropped significantly in comparison with the rest of the microcycle and the match. This new monitoring method may help practitioners to establish an accurate assessment of external load demands in competition and training.

Keywords: most demanding scenario, team sport, game analysis, training microcycle, ultra-wideband

OPEN ACCESS

Edited by:
Fábio Yuzo Nakamura, Università degli Studi "G. d'Annunzio" Chieti - Pescara, Italy

Reviewed by:
Jonathan Douglas Connor, James Cook University, Australia
Hongyou Liu, South China Normal University, China

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *29 June 2020*
Accepted: *16 September 2020*
Published: *15 October 2020*

Citation:
Illa J, Fernandez D, Reche X, Carmona G and Tarragó JR (2020) Quantification of an Elite Futsal Team's Microcycle External Load by Using the Repetition of High and Very High Demanding Scenarios. Front. Psychol. 11:577624. doi: 10.3389/fpsyg.2020.577624

Abbreviations: UWB, ultra-wideband; EPTS, electronic performance and tracking system; UEFA, Union of European Football Associations; MD, match day; MD-x, match day [MD] minus X days; GPS, global positioning system; CI, confidence intervals.

INTRODUCTION

With a view to objectively preparing players for what they may encounter during competition, coaches and strength and conditioning coaches have broadly based training prescription on match activity profile, commonly derived from the average demands of match play. However, this approach is likely to result in players being underprepared for the most demanding scenario of match play (Gabbett et al., 2016). This seems to be a common concern for most practitioners who, regardless of the method, have sought to develop alternative approaches to identify the most demanding scenario of match play, since such consideration seems to contribute to the implementation of a more accurate training program prescription (Gabbett et al., 2012). Rolling average methods have commonly been used to describe the peak periods of competition in different sports such as Australian football (Delaney et al., 2017), soccer (Malone et al., 2015; Martín-García et al., 2020), basketball (Vázquez-Guerrero et al., 2020), and rink hockey (Fernández et al., 2020).

The interest among practitioners in quantifying high-intensity running and effort bouts is not new. Some well-known examples are concepts such as repeated-sprint ability and repeated-effort ability (Spencer et al., 2004; Gabbett and Mulvey, 2008; Caprino et al., 2012; Makaje et al., 2012; Reardon et al., 2017). Another example is the concept of repeated high-intensity effort, which has been defined as three or more sprint or collision exertions during the same passage of gameplay with fewer than 21 s between each exertion (Reardon et al., 2017). Contextualized in team sports, repeated-sprint ability is defined as the ability to maintain sprint speed in the course of a game (Spencer et al., 2004), and while it is commonly accepted as a key component in high performance in futsal (Makaje et al., 2012), basketball (Caprino et al., 2012), field hockey (Spencer et al., 2004), and soccer (Gabbett and Mulvey, 2008), Gabbett (2012) reported that in collision sports such as rugby league, players were only exposed to an average of 1 repeated-sprint bout per match compared to an average of nine repeated high-intensity-effort bouts per player per match.

Although some authors have highlighted the importance of monitoring peak external workload intensities (Fox et al., 2020) in seeking to identify how many times in and between matches players perform a volume of activity that is not overly dissimilar to the identified peak period of activity (Carling et al., 2019), no research has attempted to shed some light on whether these peak demands are "one-off" (Carling et al., 2019) or present repeatedly in the course of a single match. Substantial match-to-match variability in the peak demands of competition (coefficient of variation = ∼24%) has been reported (Carling et al., 2016), suggesting that a single match may entail more than one exposure to a scenario that is very close to the most demanding scenario, hereinafter referred to as high-demanding scenario and very high-demanding scenario. This therefore renders it even more necessary to explore the possible repetition of these scenarios during a match and the training process thoroughly.

Understanding the frequency with which a player is required to manage periods with high and very high external loads that are very close to the most demanding scenario could be equally as important as the match's most demanding scenario concept. This new concept could guide strength and conditioning coaches to a more solid and systematic methodology when planning and structuring training loads during the weekly training program, particularly in a structured microcycle, understood as the training unit imparted between competitions, where also competition loads are the most important factor conditioning the rest of the sessions into systematic phases within the microcycle (Tarragó et al., 2019). An accurate periodization of these training loads is a key factor in achieving the necessary psychological and physiological adaptations that will improve individual and team performance (Akenhead et al., 2016), while reducing the likelihood of illness, injury, and non-functional overreaching (Bourdon et al., 2017).

Therefore, the main objectives of this study were (I) to describe the repetition of high- and very high-demanding scenarios of match play of an elite futsal team of the Spanish 1st Division Liga Nacional de Fútbol Sala and (II) to check if these high- and very high-demanding scenarios were represented within one competition match weekly microcycles and how they were distributed among the different training sessions.

MATERIALS AND METHODS

Design

A retrospective observational study was carried out during the 2018–2019 competitive season, and external load data were collected through an UWB electronic performance tracking system (WIMU PRO^{TM}, Realtrack Systems, Almeria, Spain). The data were collected from 13 official matches and 6 in-season training weeks with only one match per week and 4 days of training session prior to the match. The data from goalkeepers and players who played less than 5 min in the matches or did not complete the training session or match due to an injury were excluded, as were data stemming from a pre- or post-session court test. The games and training sessions analyzed were always played on the same court (always home) in the same environmental conditions. **Table 1** presents the duration of each training session and match over a 1-week period and the distribution of a total of 347 files analyzed.

Subjects

Thirteen professional elite futsal players (age: 28.8 ± 2.4 years, weight: 73.7 ± 6.2 kg, height: 175.9 ± 5.9 cm, all measurements

TABLE 1 | The duration and the total number of files across different sessions.

Match day	Duration (hours:minutes)	Total files (number of games and participants)
MD-4	01:41 ± 00:12	59
MD-3	01:39 ± 00:09	55
MD-2	01:37 ± 00:04	57
MD-1	01:25 ± 00:06	60
MD	01:33 ± 00:06	116

MD-X, match day minus days before game.

mean ± standard deviation) from a team that competes in the premier Spanish futsal league Liga Nacional de Fútbol Sala and in the UEFA Futsal Champions League participated voluntarily in the study. The data analyzed stemmed from daily player monitoring in which player activities are routinely measured in the course of the season. The experimental procedures used in this study were in accordance with the Declaration of Helsinki and were approved by the local Ethics and Scientific Committee. All the players provided their informed consent before participating.

Procedures

The number of competition matches per week, days between matches, and the physical status of the players and the team, among other conditioning factors, affected the structure of every weekly microcycle throughout the season, requiring that the technical staff adjust contents according to the Club's Structured Training Methodology (Tarragó et al., 2019) adapted to indoor team sports. Due to all these variations, this study only drew data from the weeks when players had only one match at the weekend and four consecutive training sessions (with a clear focus on the match) before the match. External training load data were analyzed with regard to the number of days prior to the match [match day (MD) minus X days] (Akenhead et al., 2016). The training sessions of the microcyles analyzed in this research were always comprised of an integrated content (i.e., tactical, technical, and physical factors were amalgamated) and are described below: MD-4 was the first training in the microcycle. The main goals of this session were to develop player strength and power capabilities through an initial individualized functional strength program performed at the gym followed by small-sided games with goalkeepers on the court. The MD-3 training session focused on developing the team's playing model. The session was structured in two main blocks, firstly addressing the transitional moments of the game through numerical advantage and disadvantage situations and secondly by working on the defensive system with repeat 4v4 situations conditioned by coach-specified constraints. The main purpose of MD-2 was to tactically and physically prepare the team and the players for the following competition match. This session consisted of working on the team's game model through real match situations by playing short matches (between 3 and 4 bouts depending on the length of each one) with different preestablished conditioning factors (i.e., point in the game, score, number of faults of each team, etc.). Each short match sought to reproduce similar playing rotations (i.e., point and length of playing time between resting periods for a player in a match) as they usually occur during the match. MD-1 was the day before the competition and was the shortest of all the sessions. It was characterized by using 4v4 (with goalkeepers) games in reduced spaces, emphasizing repeat set pieces (corner kicks and sidekicks), finishing the session with 5v4 tactical situations. The main goals of these sessions remained consistent across the competitive season for all microcycles with only one match per week and 4 days of training session prior to the match.

Data logging was carried out with a local positioning system (WIMU PRO^{TM}, Realtrack Systems SL) and its corresponding software (SPRO^{TM}, Realtrack Systems SL, version 946). The devices were placed in the upper part of the back, in tight-fitting harnesses. The WIMU PRO^{TM} is equipped with four 3D accelerometers (full-scale out output ranges are ±16, ±16, ±32, and ±400 g. 100 Hz sample frequency), three gyroscopes (8,000°/s full-scale out output range. 100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a GPS (10 Hz sample frequency), and a UWB (18 Hz sample frequency). The UWB system was installed on the court as follows: 6 antennae with UWB technology were fixed 5 m from the court perimeter line. The WIMU PRO system presented better accuracy (bias: 0.57–5.85%), test–retest reliability [% technical error of measurement (% TEM): 1.19] and inter-unit reliability (bias: 0.18) in determining distance than GPS technology (bias: 0.69–6.05%; % TEM: 1.47; bias: 0.25) (Bastida Castillo et al., 2018). More recently, the WIMU PRO system presented a high intra-class correlation coefficient (ICC) value for the x-coordinate (0.65), a very high one for the *y*-coordinate (0.85), and a good % TEM: 2 (Bastida Castillo et al., 2019).

The variables selected to describe the external load scenarios were classified in locomotor distance variables [total distance covered ($m \cdot min^{-1}$) and distance covered above 0.02 instantaneous Player Load (vector magnitude expressed as the square root of the sum of the squared instantaneous rates of change in acceleration in each of the 3 planes divided by 100) in arbitrary units (>0.02 AU; $m \cdot min^{-1}$)], locomotor velocity variables [absolute high-speed running (distance covered above 18 $km \cdot h^{-1}$; $m \cdot min^{-1}$), and relative high-speed running (distance covered above 85% of individual maximum speed recorded in training sessions or matches; $m \cdot min^{-1}$)]) and neuromuscular variables [number of high-intensity accelerations (>2 $m \cdot s^{-2}$; $n \cdot min^{-1}$) and number of high-intensity decelerations (>2 $m \cdot s^{-2}$; $n \cdot min^{-1}$)] following the Zurutuza and Castellano (2020) external load classification.

The raw data from the EPTS and its software SPRO^{TM} were computed with RStudio version 1.2.5033 (RStudio, Inc.). The data computation procedures were structured in five steps, which were always applied for each player and each variable. The first step was to determine the most demanding scenario of each match. The rolling average method with a 1-min time window was used, and the results made it possible to establish a data frame of individual maximum values. The second step was to determine a reference value (100% most demanding scenario of the MD value). For this purpose, a mean of the top three observations was taken in order to smooth possible outliers. The third step was to establish thresholds to count the number of high-demanding scenarios, very high-demanding scenarios, and high plus very high-demanding scenarios. A lower limit threshold of 90% of the reference value of the most demanding scenario was established for very high-demanding scenarios, and a lower and upper limit threshold of 80–90% of the reference value of the most demanding scenario was established for high-demanding scenarios. The fifth and last step was to re-conduct a rolling average and save not the most demanding scenario but rather all the scenarios within the defined thresholds. The final output was the total number of high-, very high-, and high plus very high-demanding scenarios for each training session and match, for each player and variable.

Statistical Analysis

All statistical analyses were conducted with RStudio version 1.2.5033 (RStudio, Inc.). Descriptive data were reported as mean ± standard deviation. The data failed all the tests for homogeneity of variance (Levene's test) and for normality (Shapiro–Wilk's test). To perform the hypothesis test to assess the differences between MDs, a bootstrap CI approach was used because the assumptions of this method were aligned with our data (Wilcox, 2010). A residual resampling model, with 10,000 bootstrap samples and 95% bias-corrected and accelerated method (BCa 95% CI), was used to calculate the CI of F-values of repeated-measure ANOVA for each variable and established that the null hypothesis, that there were no differences, was true if 1 fell within the CI limits (Plonsky, 2015). The same bootstrap CI approach with a simple resampling model was used to evaluate the *post hoc* pairwise comparisons in the variables with differences between MDs. The mean difference in the number of scenarios was computed and presented as percentage change rate (Δ%Scenario); data were presented as mean difference and BCa 95% CI in contrast plots (Ho et al., 2019; Jovanovic, 2020). All the reported P-values were the likelihoods of observing the absolute effect sizes if the null hypothesis of zero difference was true (Plonsky, 2015).

RESULTS

The descriptive data of the number of high- and very high-demanding scenarios are represented in **Table 2**. The MD-2 training session and the MD were the 2 days in the microcycle with the greatest number of scenarios. **Table 3** presents the results of the bootstrap ANOVA. In the very high-demanding scenario threshold, only in high-intensity decelerations were no significant differences found; and in the high demanding scenario threshold, no significant differences were found in absolute and relative high-speed running.

The *post hoc* analysis of the high plus very high-demanding scenario threshold is displayed in **Figure 1**. Briefly, the results showed that in absolute and relative high-speed running, MD-2 had a significantly greater number of scenarios than the other days (the greatest difference was found between MD-2 and MD-1, with a mean difference of 0.84 [BCa 95% CI: 0.54–1.15] in absolute high-speed running and 0.83 [BCa 95% CI: 0.58–1.10] in relative high-speed running), and that MD-1 had significantly fewer scenarios than the other days except in relative high-speed running between MD-3 and MD-1 (the greatest difference was found between MD and MD-1, with a mean difference of 0.45 [BCa 95% CI: 0.22–0.66] in absolute high-speed running and 0.29 [BCa 95% CI: 0.12–0.47] in relative high-speed running). Except between MD and MD-2 in total distance, MD had a significantly greater number of total distance and player load scenarios than the other days (the greatest difference was found between MD and MD-1, with a mean difference of 4.31 [BCa 95% CI: 3.84–4.80] in total distance and 2.17 [BCa 95% CI: 1.84–2.52] in player load) and MD-2 had a significantly greater number of scenarios than the other days (except with MD) (the greatest difference was found between MD-2 and MD-1, with a mean difference of 3.65 [BCa 95% CI: 2.99–4.32] in total distance and 1.52 [BCa 95% CI: 1.13–1.95] in player load), and MD-1 had significantly fewer scenarios than all other days (the greatest difference was found between MD-3 and MD-1, with a mean difference of 2.53 [BCa 95% CI: 1.85–3.48] in total distance and 0.70 [BCa 95% CI: 0.43–1.04] in player load). Finally, in high-intensity accelerations and decelerations, MD-1 had significantly fewer scenarios than all other days (the greatest difference was found between MD and MD-1, with a mean difference of 1.19 [BCa 95% CI: 0.86–1.53] in high-intensity accelerations and 0.99 [BCa 95% CI: 0.75–1.25] in high-intensity decelerations).

The *post hoc* analysis of the very high-demanding scenario threshold is presented in **Figure 2**. Briefly, the pairwise comparisons presented the same direction differences as those found in the high plus very high-demanding scenario threshold in absolute and relative high-speed running, albeit to a lesser extent. In total distance and player load, except the comparisons between MD and MD-2, the comparisons between the days were significantly different in the same direction as in the high plus very high-demanding scenario threshold.

Finally, the *post hoc* analysis of the high-demanding scenario threshold is presented in **Figure 3**. Briefly, in total distance and player load, the differences between MD and all the training days were in the same direction of the high plus very high-demanding scenario threshold; MD-2 only had significant differences with MD-4 and MD-1 in total distance and with MD-1 in player load; and MD-1, as in the high plus very high-demanding scenario threshold, had significant differences with the other days. In high-intensity decelerations, the direction and significance of the differences were the same as in the high plus very high demanding scenario threshold but of less magnitude.

DISCUSSION

This is the first study to quantify the repetition of high and very high-demanding scenarios of match play in a professional elite futsal team. It is also the first to investigate whether these scenarios are represented throughout typical one-match weekly microcycles and how they are distributed across the different training sessions. The main findings were as follows: (a) futsal players were exposed to more than one high and very high-demanding scenario in a single match, with locomotor distance variables presenting higher repeatability than neuromuscular and locomotor velocity variables, and (b) when these scenarios are compared to training, the number of exposures for players was variable-dependent and training session-dependent.

Quantification of High- and Very High-Demanding Scenarios

One of the major findings of this study was that in a single futsal match, the repetition of high- and very high-demanding

TABLE 2 | Number (mean ± standard deviation) of scenarios for each type, match day, and variable analyzed.

Scenario type	Match day	Absolute high-speed running	Relative high-speed running	Total distance	Player load	High-intensity accelerations	High-intensity decelerations
High + very high-demanding scenarios	MD-4	0.53 ± 0.80	0.49 ± 0.95	2.86 ± 2.05	0.98 ± 1.28	1.34 ± 2.43	1.03 ± 1.92
	MD-3	0.47 ± 0.69	0.35 ± 0.62	2.96 ± 2.93	0.84 ± 1.08	0.93 ± 1.51	0.65 ± 1.38
	MD-2	1.02 ± 1.04	1.00 ± 0.91	4.09 ± 2.47	1.65 ± 1.54	0.54 ± 1.04	0.51 ± 1.15
	MD-1	0.18 ± 0.54	0.17 ± 0.46	0.43 ± 0.74	0.13 ± 0.34	0.22 ± 0.64	0.13 ± 0.39
	MD	0.63 ± 0.91	0.47 ± 0.74	4.75 ± 2.45	2.30 ± 1.79	1.41 ± 1.64	1.12 ± 1.26
Very high-demanding scenarios	MD-4	0.36 ± 0.66	0.31 ± 0.73	0.58 ± 0.88	0.25 ± 0.68	0.71 ± 1.73	0.53 ± 1.24
	MD-3	0.24 ± 0.51	0.22 ± 0.50	0.56 ± 0.76	0.25 ± 0.48	0.38 ± 0.76	0.38 ± 0.95
	MD-2	0.68 ± 0.89	0.68 ± 0.85	1.00 ± 1.34	0.75 ± 1.15	0.18 ± 0.57	0.25 ± 0.85
	MD-1	0.08 ± 0.28	0.10 ± 0.35	0.10 ± 0.35	0.05 ± 0.22	0.07 ± 0.31	0.10 ± 0.35
	MD	0.37 ± 0.68	0.32 ± 0.58	1.38 ± 1.51	0.77 ± 0.98	0.58 ± 0.91	0.51 ± 0.95
High-demanding scenarios	MD-4	0.17 ± 0.42	0.19 ± 0.39	2.29 ± 1.58	0.73 ± 0.91	0.63 ± 1.31	0.51 ± 0.97
	MD-3	0.24 ± 0.51	0.13 ± 0.39	2.40 ± 2.48	0.58 ± 0.88	0.55 ± 1.03	0.27 ± 0.89
	MD-2	0.33 ± 0.58	0.32 ± 0.51	3.09 ± 1.86	0.89 ± 0.94	0.37 ± 0.64	0.26 ± 0.67
	MD-1	0.10 ± 0.35	0.07 ± 0.25	0.33 ± 0.63	0.08 ± 0.28	0.15 ± 0.40	0.03 ± 0.18
	MD	0.26 ± 0.53	0.15 ± 0.42	3.37 ± 1.88	1.53 ± 1.29	0.83 ± 1.23	0.61 ± 0.83

MD-X, session minus days before the game.

TABLE 3 | Bootstrap ANOVA results for each scenario threshold.

Variable	*F*	Bootstrap*			
		Bias	Std. error	BCa 95% CI lower	BCa 95% CI upper
ANOVA for high + very high-demanding scenarios					
Absolute high-speed running	8.186	3.016	3.482	2.341	11.661
Relative high-speed running	11.859	3.940	4.268	3.375	15.766
Total distance	52.897	14.099	10.678	33.833	57.891
Player load	36.326	9.958	8.690	19.535	42.101
High-intensity accelerations	11.828	4.152	4.681	2.665	16.236
High-intensity decelerations	8.027	3.183	3.676	1.834	11.507
ANOVA for very high-demanding scenarios					
Absolute high-speed running	7.144	2.819	3.366	1.660	10.586
Relative high-speed running	8.250	3.062	3.632	1.524	12.077
Total distance	17.800	5.478	5.626	8.740	22.561
Player load	15.448	4.964	5.242	5.511	20.086
High-intensity accelerations	6.350	2.932	3.587	1.066	9.808
High-intensity decelerations	3.198	1.857	2.245	0.186	5.564
ANOVA for high-demanding scenarios					
Absolute high-speed running	1.908	1.513	1.750	0.024	3.626
Relative high-speed running	3.345	1.860	2.331	0.247	5.784
Total distance	38.673	10.611	9.085	21.415	44.503
Player load	25.067	7.159	6.667	11.069	29.967
High-intensity accelerations	8.795	3.412	3.998	1.639	12.807
High-intensity decelerations	8.195	3.085	3.645	1.638	11.776

*The null hypothesis was rejected if 1 did not fall within BCa 95% CI limits. *Bootstrap results are based on 10,000 bootstrap samples.*

scenarios of total distance (3.37 ± 1.88 and 1.38 ± 1.51, respectively) was higher than the other variables analyzed. Additionally, repeat highly demanding bouts of player load were observed in this study (1.53 ± 1.29 high-demanding scenarios and 0.77 ± 0.98 very high-demanding scenarios), suggesting that peak locomotor distance demands are highly repetition-prone during futsal matches. It remains unclear to which degree these results may be attributed to the intrinsic low-intensity nature of the locomotor distance variables, to the idiosyncrasy of the short stoppages and interruptions during futsal matches (i.e., outsides, corner-kicks, etc.) in which players continue to move even when the ball is not in play, or to

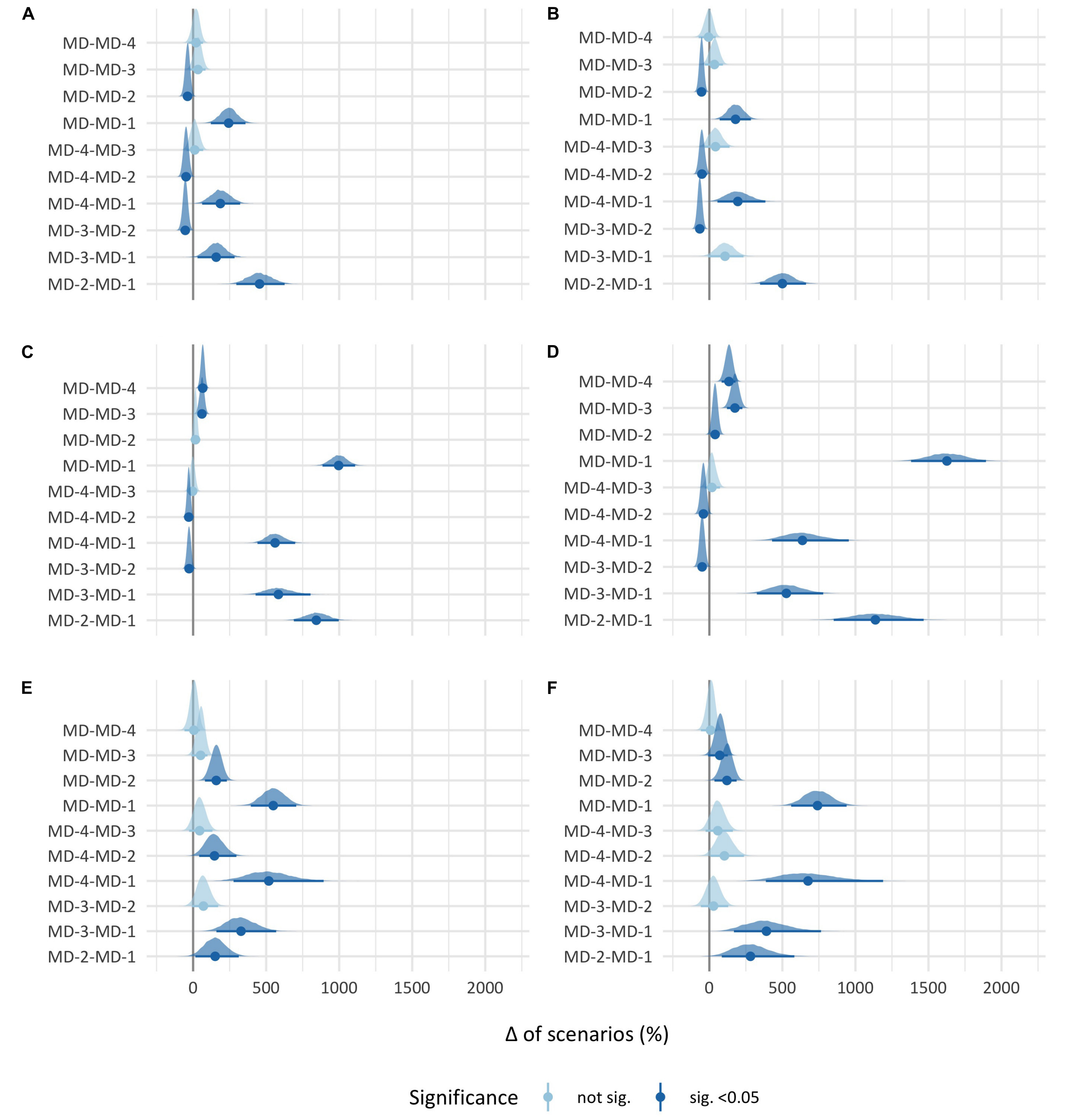

FIGURE 1 | 95% Confidence interval percentage change of high plus very high-demanding scenarios between match days. Each point represents the mean percentage change, and each black line through the point represents the 95% confidence interval of the percentage change between the two match days. **(A)** Absolute high-speed running. **(B)** Relative high-speed running. **(C)** Total distance. **(D)** Player load. **(E)** High-intensity accelerations, **(F)** high-intensity decelerations.

the playing model of the team, which is characterized by a fast-paced game play.

It is now generally accepted that the small dimensions of indoor sports courts (a futsal court is 40 m long and 20 m wide) are a limiting factor when referring to locomotor velocity variables. Small relative areas (80 square meters per player in futsal matches) are known to under-stimulate the distance covered at high speed (Martín-García et al., 2020). This is consistent with our findings and may therefore explain why absolute and relative high-speed running exhibited the

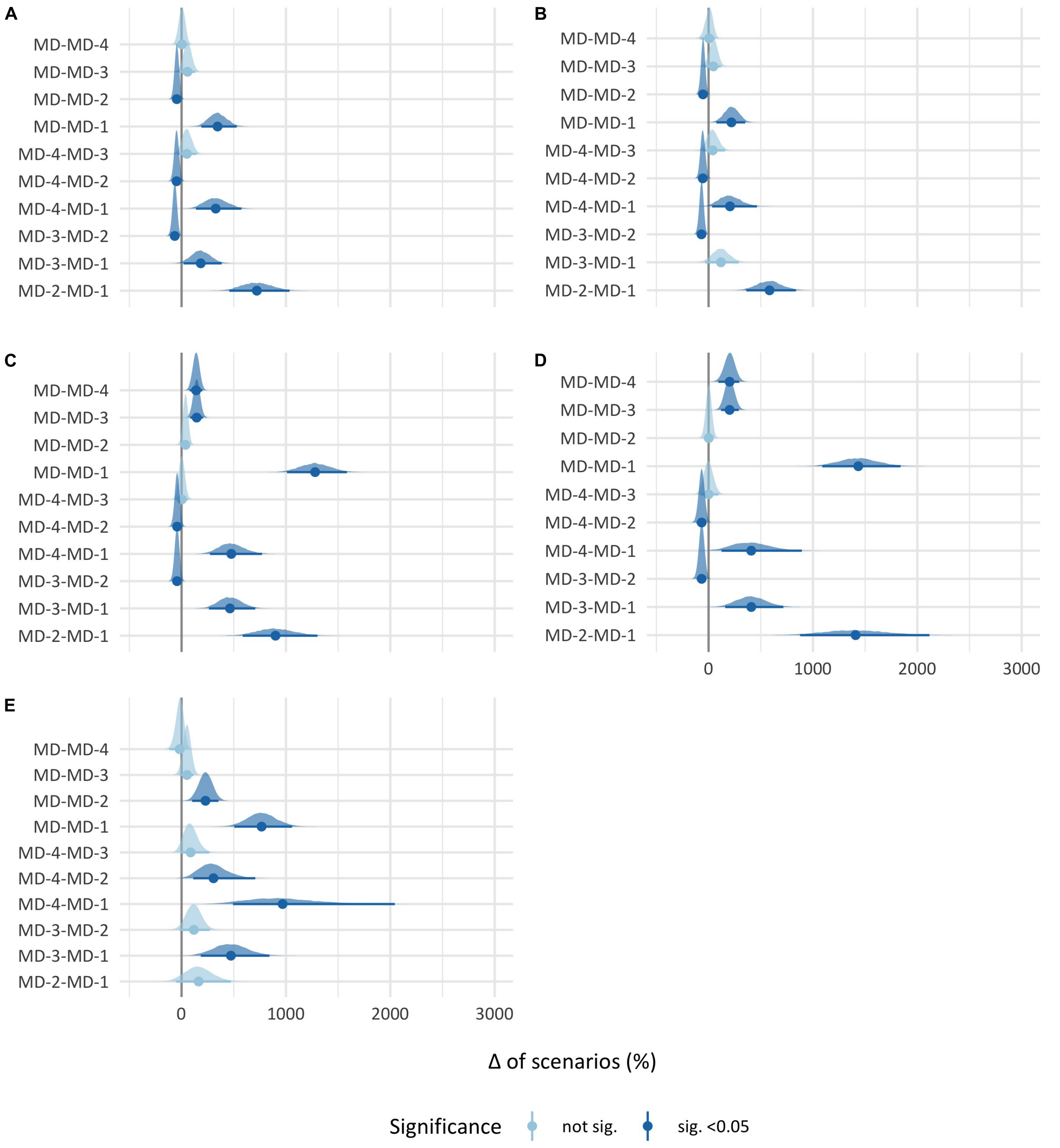

FIGURE 2 | 95% Confidence interval percentage change of very high-demanding scenarios between match days. Each point represents the mean percentage change, and each black line through the point represents the 95% confidence interval of the percentage change between the two match days. **(A)** Absolute high-speed running. **(B)** Relative high-speed running. **(C)** Total distance. **(D)** Player load. **(E)** High-intensity accelerations.

lowest number of repetitions of high- and very high-demanding scenarios during futsal matches (0.63 ± 0.91 high plus very high-demanding scenarios of absolute high-speed running and 0.47 ± 0.74 high plus very high-demanding scenarios of relative high-speed running).

This study also revealed that the team analyzed was more susceptible to the repetition of high- and very high-demanding scenarios of neuromuscular variables such as high-intensity accelerations and decelerations in a match (0.83 ± 1.23 and 0.58 ± 0.91 high-intensity accelerations

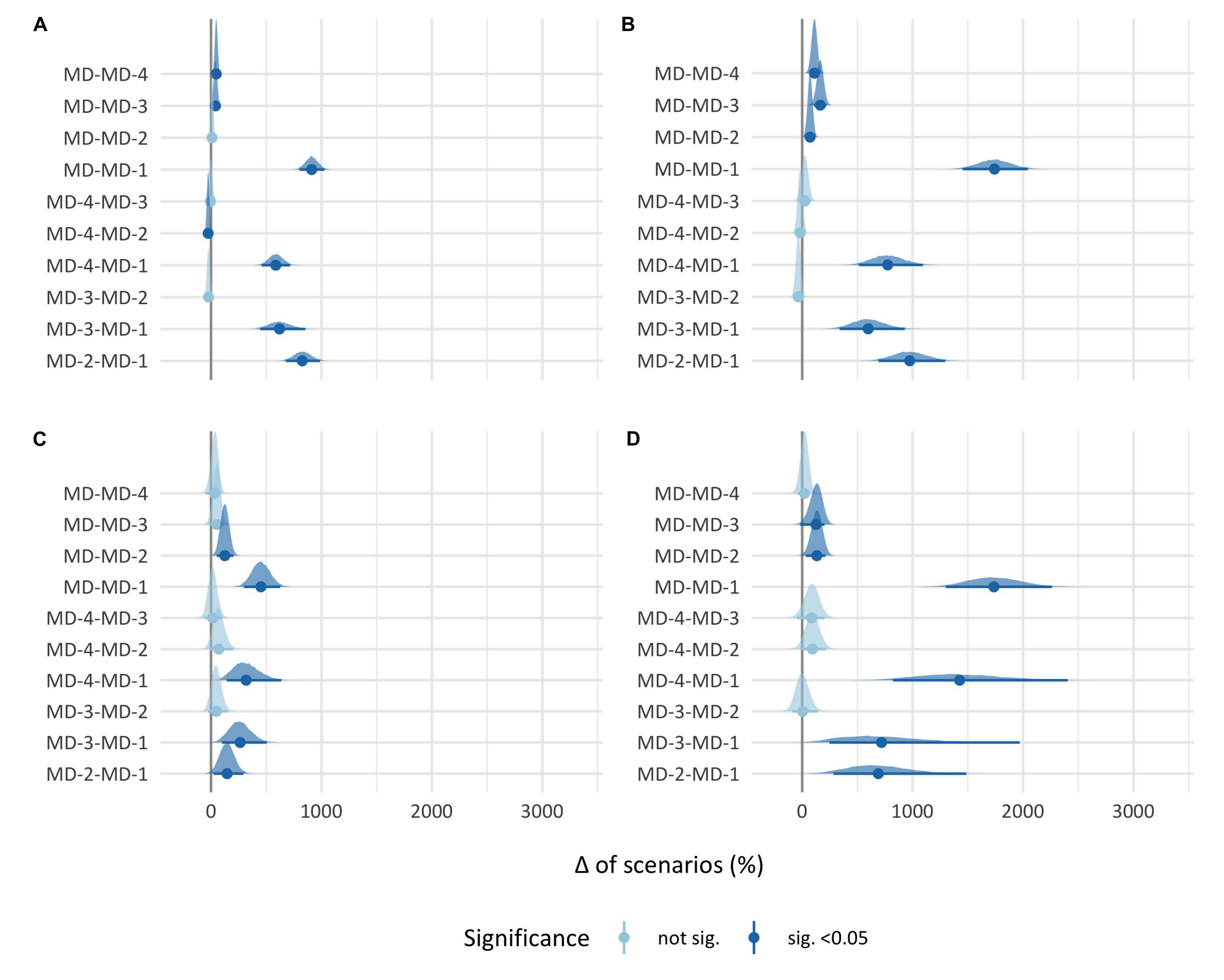

FIGURE 3 | 95% Confidence interval difference of number of high-demanding scenarios between match days. Each point represents the mean difference, and each black line through the point represents the 95% confidence interval of the difference between the two match days. **(A)** Total distance. **(B)** Player load. **(C)** High-intensity accelerations. **(D)** High-intensity decelerations.

and 0.61 ± 0.83 and 0.51 ± 0.95 high-intensity decelerations in the high- and very high-demanding scenario thresholds, respectively) than the repetition shown in relation to locomotor velocity variables. These results indicate that the overall repeatability of high- and very high-demanding scenarios in a futsal match for the team studied is lower when high-intensity variables are analyzed. However, we acknowledge, in line with the ideas of Martín-García et al. (2018a), that other activities occur within the most demanding scenario of a match. For example, as reported by Martín-García et al. (2018a), during the most demanding scenario of total distance for a 1-min time window, professional soccer players covered an average of 191.6 ± 19.7 $m{\cdot}min^{-1}$, together with 38.3 ± 23.1 $m{\cdot}min^{-1}$ of distance above 19.8 $km{\cdot}h^{-1}$, 2.6 ± 1.6 high-intensity accelerations $\cdot min^{-1}$ (>3 $m{\cdot}s^2$), and 3.5 ± 1.6 high-intensity decelerations min^{-1} (<−3 $m{\cdot}s^2$); hence, future research should further investigate other load variable behaviors while a player is exposed to high- and very high-demanding scenarios of any selected variable.

High- and Very High-Demanding Scenarios in the Structured Microcycle

When the repetition of high- and very high-demanding scenarios versus the number of training days prior to a match was analyzed, this study observed that MD-2 was the training session that best represented match high- and very high-demanding scenario repetition in locomotor distance variables, with players performing 4.09 ± 2.47 repetitions of total distance high plus very high-demanding scenarios, matching those found in the match or even surpassing the match in locomotor velocity variables (difference between MD-2 and MD of 0.39 [BCa 95% CI: 0.08–0.72] in absolute high-speed running and 0.53 [BCa

95% CI: 0.28–0.81] in relative high-speed running, in both high- and very high-demanding scenario threshold). We speculate that this parallelism between MD-2 and the match may be attributable to the nature of this type of session, in which coaches implement simulated competition sequences according to the team's game model. In line with this idea, the MD-4 particularities of the team analyzed, involving small-sided games intended to develop strength and power, seem to provide a rationale for it being the training session presenting the highest number of repeated high- and very high-demanding scenarios of high-intensity accelerations and decelerations, while also matching the demands of competition in terms of highly demanding peaks of neuromuscular activity. In this study, repeat exposure to these bouts gradually decreased on the days leading up to the match. This tallies with the findings of Martín-García et al. (2018b), who reported a progressive decrease in all metrics when quantifying the external load of a soccer team using the same structured microcycle as the one analyzed in this investigation. The small-sided games commonly used for the team studied during MD-4 would also account for the significantly lower repetition of high- and very high-demanding scenarios of absolute and relative high-speed running when compared to the match and to MD-2. Curiously, MD-3 exhibited a strong similarity with MD-4 for all variables studied, regardless of the different objectives and contents proposed by the coaches for both training session types. Another interesting finding of this study was that regardless of the variable analyzed, the number of high- and very high-demanding scenarios in MD-1 diminished compared to the rest of the training sessions. These results seem to agree with those of prior studies quantifying the external load of training microcycles in soccer (Malone et al., 2015; Owen et al., 2017; Martín-García et al., 2018b), which reported that MD-1 had the lowest external load of all training sessions within the microcycle. As suggested by Malone et al. (2015), this drop in MD-1 could be considered as a tapering-off strategy by coaches geared toward increasing player readiness for the forthcoming match.

Although this study is based on a single futsal team, the findings provide a new understanding as to how many times players have to cope with periods of activity that are close to the most demanding scenario of match play during futsal matches. One limitation of the study is the small number of training weeks included, since only six training weeks matched the inclusion criteria due to the team's busy calendar. Additionally, and given that an UWB positioning system was required to record the match data, only 13 official matches from a single team were included in the study. In spite of its limitations, the results of this study lay the foundations for future research including internal load variables together with the description of the activities performed by the players during the high and very high demanding scenarios in a given tactical context.

CONCLUSION

The analysis of the repetition of high- and very high-demanding scenarios undertaken in this study support the idea that high demands of competition present repeatedly in the course of a single match instead of being a "one off" event (Carling et al., 2019), providing a new method to monitor and quantify the most demanding scenario demands in match play. From the training prescription standpoint, the findings of this study show that the team in question experience the overall repeatability of high- and very high-demanding scenarios performed during competition throughout each systematic phase of the structured microcycle by stressing the high- and very high-demanding scenarios of neuromuscular and locomotor velocity variables at the beginning of the week and the high- and very high-demanding scenarios of locomotor distance variables 2 days prior to the match, leaving the closest training session to the match without stressing any of these scenarios.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee for Clinical Research of the Catalan Council, Generalitat de Catalunya, Spain. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JI participated in the design of the study, contributed to data collection and interpretation of results, and contributed to the manuscript writing. DF participated in the design of the study, contributed to data reduction, analysis, and interpretation of results, and contributed to the manuscript writing. XR participated in the design of the study, contributed to data reduction, analysis, and interpretation of results. GC contributed to the manuscript writing. JT participated in the design of the study and contributed to the manuscript writing. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 26 October 2020
doi: 10.3389/fpsyg.2020.591572

Development of Defensive Actions in Small-Sided and Conditioned Games With Offensive Purposes in Futsal

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Based on ecological dynamics approach, non-linear pedagogy (NLP) have emerged with the goal of promoting a holistic approach through the use of small-sided and conditioned games (SSCGs), to optimize specific tactical defensive and offensive behaviors of players. This study analyzed the indirect effects of an intervention program, based on NLP (task design based on tactical principles of attack and numerical advantage of attacking team), in decision-making (DM) and execution (Ex) in defensive technical–tactical actions in U16 futsal. Eight futsal players (U16 years) participated in 12 training sessions, spread over two phases: preintervention and intervention. The Game Performance Evaluation Tool (GPET) instrument was used to analyze the DM and Ex of 2,600 defensive actions measured during competitive matches. Results showed significant improvements in marking actions (to the player with the ball: DM, $p = 0.001$; Ex, $p = 0.001$; and to the player without the ball: DM, $p = 0.039$; Ex, $p = 0.046$), improvements in blocking actions (DM, $p = 0.015$), and improvements in help-coverage actions (Ex, $p = 0.014$). No significant differences were found in the interception and tackling actions. This study has shown evidence that the NLP approach is an appropriate theoretical framework to enhance acquisition of defensive tactical behavior in futsal. However, not all actions improved. Therefore, coaches should design representative tasks to optimally develop technical–tactical training processes based on the phases of futsal game (offensive and defensive) and considering the level of opposition.

Keywords: futsal, defensive actions, task constraint, performance analysis, non-linear pedagogy

OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *04 August 2020*
Accepted: *30 September 2020*
Published: *26 October 2020*

Citation:
Pizarro D, Práxedes A, Travassos B and Moreno A (2020) Development of Defensive Actions in Small-Sided and Conditioned Games With Offensive Purposes in Futsal. Front. Psychol. 11:591572. doi: 10.3389/fpsyg.2020.591572

INTRODUCTION

In team sports such as futsal, in which predominate open motor skills, it is required that players continuously coadapt their actions to the movements of opponents and teammates to ensure a functional collective behavior (Chow et al., 2016). It is a sport where tactical components assume a fundamental role in the effectiveness of each game action (López, 2017). Tactical behavior is a general concept that helps to explain how players guide behavior to functionally perform. From the perspective of ecological dynamics, tactical behavior is an active and continuous process of searching and exploration of relevant information to perform under the changes of the game

(Gonçalves et al., 2014), which can be considered into two specific phases of game, according to game requirements: (a) with ball possession (offensive actions) and (b) without ball possession (defensive actions) (Corrêa et al., 2012). Despite the importance of achieving functional tactical behavior in both phases, it is generally considered that the development of defensive tactical behavior is usually considered of low priority when compared with offensive ones (Martiño, 2018). Indeed, previous research has ignored the analysis and development of defensive tactical behaviors (Reis et al., 2019), even being a key moment in the motor learning phase in team sports (Memmert and Roth, 2007).

López (2017), in a book from the European Union of Football Association (UEFA), referred that, to optimally develop the training processes of the defensive phase of futsal game, coaches should develop defensive tactical behavior of players by highlighting: (a) the perceptual demands associated with defensive actions [such as the identification of ball trajectory, position of teammates and opponents, orientation of the game (offensive orientation of the holder of the ball and collective defensive orientation based on the strong side–weak side), and the level of pressure on the ball (passing lines and direction of play of the offensive game)]; (b) the defensive foundations that support players' defensive actions (man-marking, controlling the space, putting pressure on the ball, commanding the space, floating cover, switching opponent, closing/blocking passing angles. . .); and (c) the defensive game principles that support collective behavior (recover the possession of the ball, prevent progression, and avoid the goal (Bayer, 1992; Martiño, 2018), the strategic requirements that support collective behavior under game context [such as the type of defense used (individual or marking zone), the collective defensive moves according with the ball position on the field, or even the defensive tactical intention according to risk assessment (result, time.)] (see **Table 1**).

Thus, to improve players' tactical defensive behavior, it is required that the design of training tasks exposes players to game contexts that sample the perceptual-motor and strategic demands of competition according to the level of players (Travassos et al., 2012b; Xavier de Andrade, 2019). That is, training tasks and the consequent main goals should highlight perceptual, action, and strategic requirements of players' actions according to players' development and actual action capabilities.

In the last few decades, based on ecological dynamics approach, non-linear pedagogy (NLP) have emerged with the goal to promote a holistic approach through the use of small-sided and conditioned games (SSCGs) (Chow et al., 2016). The use of SSCG allows coaches to optimize specific tactical defensive and offensive behaviors of players by breaking the game in specific game subunits, i.e., GK + 1 × 1 + GK until GK + 3 × 3 + GK (Sampaio and Maçãs, 2012) instead of replicating the general demands play of real match (Aguiar et al., 2012; Sarmento et al., 2018). In line with this, coaches should go from simplified units with low number of players, to highlight the informational constraints that promote the development of defensive foundations of players, to more complex units until the numerical relation of the game to develop the game principles and strategic requirements that support collective behavior of teams according to the perceptual and action demands of competition. As such, modifying the number of players during the SSCG can lead to different opportunities for action.

Therefore, other types of constraints should be explored to assist coaches in the creation of more adjusted learning environments to their purposes (Santos et al., 2020). Different task constraints can be manipulated to boost the discovery and exploration of players' movement solutions (Hristovski et al., 2011). To promote such motor exploration for adaptability, the available research has been suggesting the creation of tasks with additional variability (Seifert et al., 2013). In line with this, functional variability, as a principle emanating from an ecological dynamic (Chow, 2013), encourages the emergence of functional movement solutions within game situations (Schmidt and Lee, 2019) through improvement of perceptual attunement (i.e., capability to identify and explore the better information for performance in each context of practice) and motor calibration (i.e., capability to adjust movement solutions to spatial–temporal conditions of game) to game environments (Seifert et al., 2013; Pizarro et al., 2019).

In this perspective, the teaching process should be focused on the manipulation of relevant task constraints that highlight the informational constraints that support and guide players toward the functional resolution of each task goals according to the coaches' main purposes (Passos et al., 2008). This is particularly relevant since they change the way players explore and act on the game context (Passos et al., 2008). In this line, it seems to indicate the different scenarios leading to the development of different capabilities through the emergence of different adaptive actions (Gonçalves et al., 2016). Therefore, to accomplish the main purpose of the development of, for instance, defensive players' behavior, it assumes a major relevance of knowing which task constraints guide players to better exploit defensive individual fundamentals and actions or collective behavior according to their age or skill level (Davids et al., 2013; Gonçalves et al., 2016).

Previous studies clearly revealed how the modifications of task constraints can change players' behavior (Travassos et al., 2014a; Vilar et al., 2014; Castellano et al., 2016; Gonçalves et al., 2017; Ometto et al., 2018). Curiously, task constraints as task aim (specifically the accomplishment of game principle to perform), balance on the number of outfield players, or instructional strategies as questioning are recently being studied (Sampaio et al., 2014; Travassos et al., 2014b; Serra-Olivares et al., 2015; Pizarro et al., 2019).

However, studies that analyze actions based on defensive game principles are not found in the scientific literature. In this sense, although the NLP approach, and more specifically the modified games, works in a holistic way the phases of attack and defense, if we design training programs focused on tactical principles of attack and with offensive numerical superiority, will the defensive technical–tactical actions improve?

Therefore, the main objective of this study was to analyze the indirect effects on defensive tactical behavior caused by the application of an intervention program based on attack, from the perspective of NLP (task design based on tactical principles of attack and offensive numerical advantage), on different defensive technical–tactical actions futsal.

TABLE 1 | Relations between technical–tactical actions with foundations that support players' defensive actions and the defensive game principles.

Defensive game principles	Defensive foundations	Technical-tactical actions
Recover the possession of the ball	Obstruction of pass lines Individual aspects of marking Pressure to the ball	Marking *(defensive action to player with the ball)*, tackling; marking *(defensive action to player without the ball)*, interception and help coverage
Prevent progression	Defensive organization Timing Pressure to the ball Defensive deployment	Marking (*defensive action to player with the ball*), marking *(defensive action to player without the ball)*, interception and help coverage Marking *(defensive action to player with the ball)*
Avoid the goal	Obstruction of shots Individual aspects of marking	and blocking

Self-made figure based on Contreras Jordán et al. (2001) and López (2017).

MATERIALS AND METHODS

Participants

The participants were eight male futsal players from the Under-16 category from two Spanish clubs (natural group not modified for research) as that of Pizarro et al. (2019). All had the same age (M = 15.375 and SD = 0.517) and level of expertise (i.e., average skill level) and participated in a regional league. In addition, players had sport expertise in futsal (M = 4.875, SD = 3.313).

The research project was fully approved by the Ethics Research Committee of a Spanish University. The research was developed under the recommendations of the Declaration of Helsinki, with respect to participant assent, parent/guardian consent, confidentiality, and anonymity. The participants and their parents were informed of the study, and an informed written consent was obtained from the parents/guardians.

Design and Procedures

The study design consisted of an intragroup design, from a quasi-experimental methodology, where two research phases were considered. In the first phase, named preintervention phase, the values of decision-making and execution were recorded for the defensive actions analyzed [decision-making (DM) and execution (Ex)] in three competition matches, as indicated by previous studies (Práxedes et al., 2018b). This first measurement allows to establish the previous level of the players. In the second mentioned phase, i.e., intervention phase, the intervention program was developed. This program had a duration of 12 training sessions (minimum recommended by studies such as Harvey et al., 2010). As in the previous phase, the variables analyzed (DM and Ex) were recorded in competitive matches.

Intervention

In preparation for the intervention, several meetings were conducted between the coach and the main research with the following goals: (a) discussion of NLP approach, (b) definition of discussion practice task contents, (c) design of tasks based on the principles of NLP, and (d) test of the tasks designed in a futsal team of the same age category as the participants of the present study (Harvey et al., 2010; Práxedes et al., 2016).

The design was conducted in 12 training sessions ($\geq$ 12, as recommended by Harvey et al., 2010), 2 weekly sessions, for 6 weeks. In each training session, there were four learning tasks (without an active recovery between them) each lasting a total of 15 min, which was based on the use and manipulation of SSCG (see the example in **Table 2**). Extra balls were placed around the field to allow a quick restart of the task in case the ball went out of bounds. It is important to point out that there was no warmup because the intensity of the tasks was increasing.

More specifically, each modified game focused on the development of one of the offensive tactical game principles (Bayer, 1992). In this sense, the aim of the first task was to keep the ball possession; the aim of the second task was to progress toward the opposite goal, and that of the third was destined to the development of the principle to shoot at goal with the lowest level of opposition. No coach feedback or encouragement was allowed during the first (7 min) and the second (7 min) part of each task. Questioning was only implemented in the middle part of each task (1 min), from an ecological perspective (questions thrown by the coach in order to guide the players toward the objectives of the task without a conversation between them).

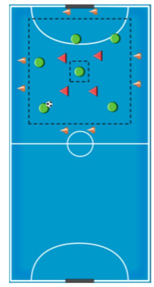
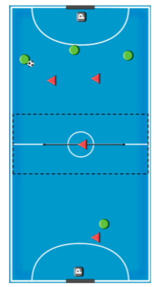
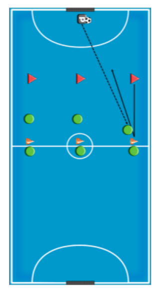
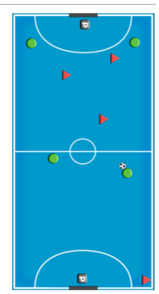
On the other hand, the level of opposition (level of numerical unbalance) was considered (Sampaio et al., 2014; Práxedes et al., 2018a). In all the tasks considered, a numerical superiority in attack was observed to highlight different offensive principles. Even not being the main goal of each SSCG, concurrently defensive foundations and tactical principles of play were also present in each task, allowing defensive players to also develop their defensive tactical capabilities of play.

The percentage of work of each defensive content was calculated for each exercise (see **Figure 1**). Each content in each task was registered as "1." At the end of all sessions, the sum of each content was divided by the sum of total contents of sessions (in our case 82) to calculate the percentage of work of each content; for example, "individual aspects of marking:" 12/82 = 15%).

Data Collection

The tactical defensive behavior of players was analyzed by considering DM and Ex of player's behavior. To assess the DM and Ex of players, the Game Performance Evaluation Tool (GPET) observation instrument was used. This instrument permitted evaluating the player's tactical problem-solving skills, by means of selecting an appropriate technique,

TABLE 2 | Example of a training session.

Contents		Explanation	Figure
Main contents: Pass and interception. Output pressure–pressure. Introduction to 4vs3.			
1	*Attack*: Generate pass lines. Keep the ball possession. *Defense*: [gp]Recover the possession of the ball. [df]Obstruction of pass lines, individual aspects of marking and pressure to the ball.	*Organization*: 6vs4 in 1/2 of the court with two defined zones (the playing area and a central area). *Task aim*: to keep the ball possession (5 passes = 1 point). If the defense intercept and recover the ball possession, they must try to score in one of the four goals at the first touch, to achieve 1 point. *Rules*: in the central area there must always be an attacker.	
2	*Attack*: Progress toward the opposite goal. Overcome the first opposite pressure line. Successfully finish the attack in superiority. *Defense*: [gp]Prevent progression and avoid the goal. [df]Defensive organization, timing, pressure to the ball and defensive deployment.	*Organization*: 3vs2→3vs2. There were defined three zones (output pressure–pressure, medium zone, and finish zone). *Task aim*: to progress toward the opposite goal. First, 3vs2 for ball output pressure. Once the pressure is released, they raise 2 of the first 3 to the attack (those who have not given the pass), generating another 3vs2 against two defenders located on the opposite court. *Rules*: attackers have to get out of the pressure by passing (never by dribbling).	
3	*Attack*: Shoot at goal with the lowest level of opposition. *Defense*: [gp]Prevent progression and avoid the goal. [df]Defensive deployment and timing. Obstruction of shots Individual aspects of marking	*Organization*: 3vs1→3vs3 in 1/2 of the court. *Task aim*: shoot at goal. Therefore, one of the three attackers have to receive the ball from the goalkeeper. *Rules*: the two defenders not facing the receiver of the ball have to touch the cone and retreat to avoid the 3vs1. *Variation*: 3vs2→3vs3. In this situation, the retreat is made only by the defender facing the attacker who receives the ball	
4	*Attack*: Successfully manage situations of numerical superiority. Output pressure. *Defense*: [gp]Recover the possession of the ball, prevent progression and avoid the goal. [df]All defensive foundations included in **Figure 1**.	*Organization*: 5vs5. They were defined two zones (opposite field and own field). *Task aim*: real game with numerical superiority 4vs2 in the own field and 4vs3 in the opposite field. *Rules*: only 2 defenders will be able to defend the output-pressure in the opposite field. Only one of those two will be able to defend together with the two of own field (simulating a player sent off).	

[gp]game principles; [df]defensive foundations.

and evaluating the measure in real-game situations, as recommended by Travassos et al. (2013).

Decision-making, as the process whereby athletes select one type of attack from a series of alternatives to execute it at a specific moment and in a real-game situation (Bar-Eli et al., 2011), was measured as the percentage of successful decisions over the total number of decisions made (García-López et al., 2013). The decision-making assessment was based on indirect and external systematic observation, a methodology that had been used in previous studies to measure players' decision-making in real-game situations, which represents the influence of the environment on decision-making (Travassos et al., 2013). Through this instrument, decision-making was coded as 1 if successful (e.g., for marking action, defender tries to maintain the placement between the ball and the goal defended) or 0 if unsuccessful (e.g., for blocking action, defender does not try to block a shot) (García-López et al., 2013).

Execution, as the performance, outcome, or the final result of the motor execution (Bar-Eli et al., 2011), was measured by the percentage of successful execution over the total number of executions made (García-López et al., 2013). Through this instrument, execution was coded as 1 if successful [e.g., for

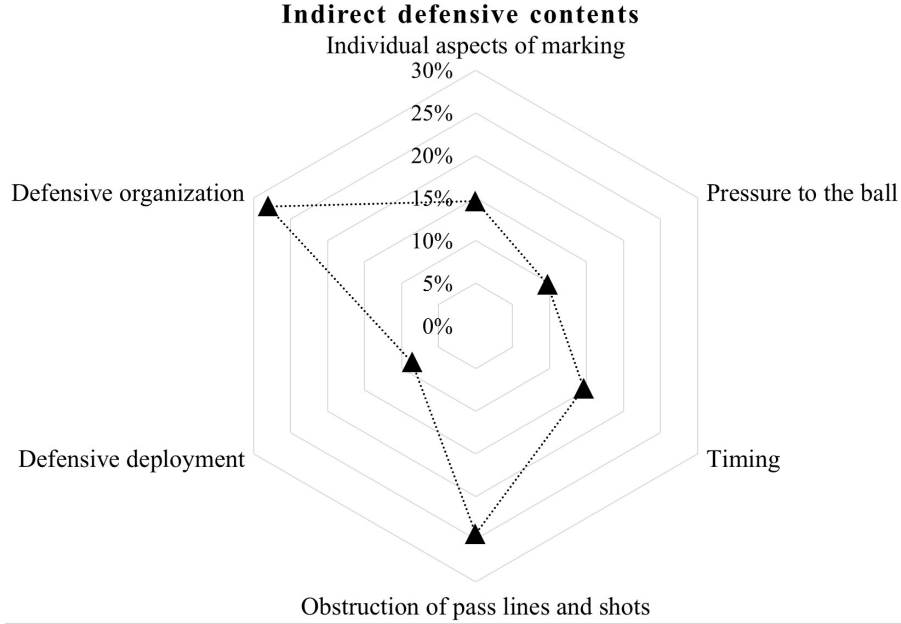


FIGURE 1 | Percentages of indirect work for each of the defensive foundations included as contents in training session. Self-made figure based on López (2017).

tackling action, defender tries to recover the ball when he has an advantage (bad control or unsafe dribbling by the attacker player)] or 0 if unsuccessful (e.g., for marking action to the player without the ball, the marked attacker gets an advantageous position) (García-López et al., 2013).

The technical–tactical actions were analyzed considering if the defender marked the player with the ball (marking, blocking, and tackling) or the attacking players without the ball (marking, interception, and help coverage). Marking the player with the ball is defined as an action in which the defender will be placed between the opponent, the ball and the goal; interception is understood as the moment in which a defender stops an offensive action of the opponent throwing himself directly to the ball; tackling as a technical action allows the defender to conquer or move away the ball that is in the possession of an opponent; marking the player without the ball is an action in which the defender must always be placed between the opponent and the goal, inside the triangle formed by the position of the ball, that of the attacker, and the center of the goal; blocking is an action done by placing the body itself between the attacker who throws the ball and the goal that is defended, along a straight line that joins the direct rival with the goal itself; and help coverage is an action depending on the position of the attacker in relation to the ball and the goal, that is when the attacker is farther, there is more coverage and less marking (López, 2017).

A total of 2,600 actions were observed. With respect to the defense actions of the player with the ball, the players developed 831 markings, 115 blockings, and 400 tacklings. In relation to the defense actions to the player without the ball, the players developed a total of 892 markings, 234 interceptions, and 128 help coverages.

All the game actions were recorded in official matches (two parts of 20 min at stopped clock) using a video camera, recording angle conversion lens (× 0.75): VCL-HGA07B and a Hama Gamma tripod Series. The camera was always placed in the background of the playing field, at a height of 4 m, guaranteeing an optimal view of all the game actions. Videos were transferred to a computer (Acer Aspire E15). Subsequently, data were recorded on a Microsoft Office Excel 2010 sheet and exported to the SPSS Inc., Released 2009 (PASW Statistics for Windows, Version 18.0, Chicago: SPSS Inc.).

Reliability

With respect to the interobserver reliability, a research observer was trained to analyze decision-making and the execution of marking (to the player with and without the ball), blocking, tackling, interception, and help coverage. He was trained by a soccer expert (Level 2 by the Spanish Soccer Federation), who also had 4 years' experience in observational methodology (researcher with experience in research projects).

As a preparatory stage to the observations, the expert met with the observer to clarify possible doubts about the observation instrument and the coding criteria of each dependent variable (DM and Ex) on the actions mentioned. Then, the observations were carried out. A total of 125 markings, 18 blockings, and 60 tacklings (defense actions of the player with the ball) and 134 markings, 35 interceptions, and 19 help coverages were analyzed, using a sample higher than 10% of the total (Tabachnick and Fidell, 2007). Interobserver reliability was calculated using the following formula: agreements/(agreements + disagreements) × 100 measure. Once this value was calculated, the Cohen kappa index was used. Values above 0.90 were obtained for all training sessions, surpassing the value of 0.81 from which adequate concordance is considered (Fleiss et al., 2003), thus achieving the necessary reliability for the subsequent coding of the dependent variables.

To guarantee the time reliability of the measurement, the same coding was developed at two different moments, with a time difference of 10 days. Cohen kappa values were found to be higher than 0.92, which reflected a reliable concordance.

Statistical Analysis

The statistical software SPSS Inc., Released 2009 (PASW Statistics for Windows, Version 18.0, Chicago: SPSS Inc.) was used for data analysis and processing. Data normality was examined and confirmed by the Shapiro–Wilk test, which led to the use of parametric statistics. Descriptive statistics were calculated, obtaining the mean (M) and the standard deviation (SD) for all variables; to examine the possible differences between the two phases considered in the study, preintervention and intervention, a multivariate analysis of variance (MANOVA) of repeated measurements of a single group was carried out. The Bonferroni's *post hoc* test was used to make multiple paired comparisons and identify the significant differences. Effect sizes were calculated using the partial eta-squared statistic (η_p^2). The effect size (ES) was classified as no effect ($\eta_p^2 < 0.04$), minimum effect ($0.04 < \eta_p^2 < 0.25$), moderate effect ($0.25 < \eta_p^2 < 0.64$), and strong effect ($\eta_p^2 > 0.64$) (Ferguson, 2009). The level of statistical significance was established at $p \leq 0.05$, with a confidence interval for differences set at 95%.

RESULTS

The pairwise comparisons between the two phases of the study regarding the action are presented.

Defending Actions to Player With the Ball

The analysis of the marking actions to the player with the ball revealed significantly higher values for the intervention phase compared to the preintervention phase in DM ($p = 0.001$) and Ex ($p = 0.001$). On the other hand, for blocking actions, significantly higher values were observed in favor of the intervention phase compared to the preintervention phase in DM ($p = 0.015$), which did not happen for the Ex variable ($p = 0.270$). Finally, there were no significant differences in any of the variables analyzed for the tackling actions (DM, $p = 0.498$; Ex, $p = 0.471$) (see **Table 3**).

Defending Actions to Players Without the Ball

The analysis of marking actions to the player without the ball revealed significantly higher values for the intervention phase compared to the preintervention phase in DM ($p = 0.039$) and Ex ($p = 0.046$). In contrast, no significant differences were found for any of the variables analyzed in the interception actions (DM, $p = 0.777$; Ex, $p = 0.336$). Finally, for help-coverage actions, significantly higher values were observed in favor of the intervention phase compared to the preintervention phase in Ex ($p = 0.014$), which did not occur for the DM variable ($p = 0.132$) (see **Table 4**).

DISCUSSION

The aim of this study was to analyze the indirect effects of an intervention program, based on NLP (task design based on tactical principles of attack and numerical advantage of attacking team), in DM and Ex in defensive technical–tactical actions in U16 futsal. These variables were analyzed considering, on the one hand, the defender that marked the player with the ball (marking, blocking, and tackling) and, on the other hand, the defenders that marked the attacking players without the ball (marking, interception, and help coverage).

Generally, results revealed that, for defending actions to the players with the ball, players improved DM and Ex of marking actions and DM for blocking actions. In addition, in the defending actions to the player without the ball, players improved DM and Ex of marking actions and Ex for help-coverage actions. Any other variable revealed improvement after the training program.

In relation to the defensive actions to the attacking player with the ball, an improvement in the DM and Ex of *marking* was observed. It means that defensive players try to maintain the alignment with the goal according to the ball position. Thus, such results highlight that numerical unbalance help defensive players to focus their attention to informational variables that sustain their actions of marking, even in a context of high variability and uncertainty (Travassos et al., 2014b). Marking in futsal, for example, can be developed with an opponent attempting to pass the ball (perform under offensive pressure based on an attack player with the ball or not) and under variable task constraints [game rules, numerical balanced (i.e., 1vs2, 2vs3...) and space].

Regarding the improvement in the DM of the *blocking*, previous analysis of the spatial–temporal principles that shaped successful shoot interceptions revealed that defenders seek to maintain their position between the ball and the goal, not allowing a misalignment between the ball and the goal (Vilar et al., 2012). As with previous studies, variability in the attacking players' relations with opponents and the ball is attributed to their constant explorative performances as they seek to break symmetry with the defending players in view of creating opportunities for scoring goals (Corrêa et al., 2012). However, the explorative behaviors of the attacking team take place under the constraints imposed by the behaviors of the defending team. As noted, the latter tries to maintain spatial–temporal relations with the former, whereas the former attempts to disrupt the *status quo* at opportune times, by advancing position in the field, reaching the free attacking player, and finding chances for goal-scoring possibilities (Travassos et al., 2014b). Thus, it can be argued that a large percentage of tasks worked, indirectly, on the content "obstruction of pass lines and shots."

In line with the first argument, due to the fact that defense always played in numerical inferiority, on very few occasions, players were able to "tackle and try to regain the possession," a very serious error in this type of situations (López, 2017). Therefore, the options for making successful tackling decrease considerably. Instead, it must be timed, obstructing passing lines to reverse this situation of superiority and turning it into an apparent equality. Previous studies such as that carried out

TABLE 3 | Descriptive analysis and comparison by pairs of DM and Ex of defense players to the attacker with the ball.

	Var.	Pre (I)			Int (J)			p	η_p^2	ES	Differences 95% CI	
		M	SD	CV%	M	SD	CV%				LL	UL
Marking	DM	0.325	0.140	0.431	0.632	0.046	0.073	**0.001**	0.870	Strong	0.403	0.555
	Ex	0.247	0.078	0.316	0.490	0.097	0.198	**0.001**	0.835	Strong	0.307	0.431
Blocking	DM	0.982	0.047	0.048	0.762	0.156	0.205	**0.015**	0.655	Strong	0.801	0.844
	Ex	0.619	0.441	0.712	0.377	0.182	0.483	0.270	0.197	Minimum	0.303	0.693
Tackling	DM	0.863	0.108	0.125	0.830	0.083	0.100	0.498	0.080	Minimum	0.777	0.917
	Ex	0.670	0.103	0.154	0.641	0.136	0.212	0.471	0.090	Minimum	0.554	0.758

Var, variable; M, mean; SD. standard deviation; CV%, coefficient of variation; ES, effect size; DM, decision-making; Ex, execution; Pre, preintervention phase; Int, intervention phase; CI, confidence interval; LL, lower limit; UL, upper limit. Values in bold indicate "significant difference" ($p < 0.05$).

TABLE 4 | Descriptive analysis and comparison by pairs of DM and Ex of defense players to the attacker without the ball.

	Var.	Pre (I)			Int (J)			p	η_p^2	ES	Differences 95% CI	
		M	SD	CV%	M	SD	CV%				LL	UL
Marking	DM	0.521	0.130	0.250	0.691	0.133	0.192	**0.039**	0.535	Moderate	0.514	0.699
	Ex	0.518	0.132	0.255	0.671	0.126	0.188	**0.046**	0.513	Moderate	0.501	0.689
Interception	DM	0.981	0.031	0.032	0.979	0.027	0.028	0.777	0.014	No effect	0.954	1.007
	Ex	0.824	0.135	0.164	0.884	0.090	0.102	0.336	0.154	Minimum	0.775	0.935
Help-coverage	DM	0.762	0.221	0.290	0.934	0.126	0.135	0.132	0.337	Moderate	0.733	0.963
	Ex	0.480	0.286	0.596	0.915	0.153	0.167	**0.014**	0.663	Strong	0.552	0.844

Var, variable; M, mean; SD, standard deviation; CV%, coefficient of variation; ES, effect size; DM, decision-making; Ex, execution; Pre, preintervention phase; Int, intervention phase; CI, confidence interval; LL, lower limit; UL, upper limit. Values in bold indicate "significant difference" ($p < 0.05$).

by Travassos et al. (2014b) indicate that, when the defending team is in numerical inferiority, the distance between the defenders decreases and the defender–attacker distance increases. Therefore, how are players going to do tackling if the attackers are so far away?

In line with previous paragraphs, NPL advocates the use of open contexts impregned of variability and uncertainty but in which the manipulations guide players to become more proficient at perceiving environment cues and constant changes in game situations (Santos et al., 2016). This is an important way to facilitate the emergence of novel and functional solutions through adaptive movement patterns. In this sense, the use of more ecological training situations allows players to attune relevant sources of information based on information–movement coupling. Consequently, the manipulation of task constraints is extremely important to promote randomness in player's actions. Moreover, this dynamical change develops exploratory behavior that encourages players to discover new action possibilities (Santos et al., 2016). In relation to *marking* (defensive actions of the attacking player without the ball), the numerical superiority in training tasks can help to improve players' attunement to information through the reduction in the information that players need to pick up to perform.

Regarding the non-improvement in the *interception* actions, it can be pointed out that, in the training tasks, there is hardly any possibility that these will happen. Thus, there is no transfer to the real matches. As Travassos et al. (2014b) point out that, when players are in numerical inferiority, they get closer to each other and close the spaces trying to protect the goal. This means that defenders restricted space between themselves and, consequently, the occupied area in front of the goal (Sampaio et al., 2014), thereby restricting space for external kicks, diagonal or longitudinal passes to the free player (Travassos et al., 2011). In this regard, usually the defender near the ball approaches the attacker with the ball to avoid progression and the defender that is marking the attacker without ball tends to close crossing passing lines that disrupt defensive structure or shooting lines to the goal (Travassos et al., 2011). On the other hand, following the informational constrains that sustain successful passes vs. interceptions of passes, changes in emergent spatial–temporal interactions and the consequent patterns of coordination between teams are expected between game conditions (Vilar et al., 2014). In this sense, these constraints are likely promoting changes in the breadth of attention and in tactical behavior of players (Memmert and Roth, 2007). However, our results suggest that playing with one less defender (underload) might not impact greatly on the capacity of a defensive team to intercept the passes by players in the attacking team.

Referring to *help-coverage* actions, the fact of having worked in numerical inferiority has allowed a greater breadth of attention of defenders to protect the position of the defender that is marking the attacker with the ball. In line with that, Torrents et al. (2016) revealed that the use of numerical unbalance game contexts when compared to balance ones allows players to explore more individual and collective tactical/technical actions that support their success. It is likely that, in this study, even though the help-coverage actions do not make the appropriate decisions, this low skill of the attacking player in the dribbling action allows to achieve success in the Ex of the defensive action.

Summarizing, the development of training exercises with numerical disadvantage promotes strong couplings between players of the defending team, the ball position, and the goal and not with the attacking players, which demonstrates how the defenders prioritize protecting the goal against ball displacements more so than against movements of the attackers (Tenga et al., 2010). As observed in previous research (Travassos et al., 2012a), it seems that the defending team adopted a zone defense with the focus of maintaining all players between the ball and the goal, resulting in the defending players trying to move in synchrony with the ball and so maintain balance with the attacking team. This behavioral change shows a tactical adaptation of the defending team under changing game conditions to constrain space and time of the attacking team. This tactical behavior assists the defending players in obtaining extra time for positioning themselves on the field to maintain spatial–temporal pressure on the attacking team to try and close their shooting and, especially, their passing lines (Travassos et al., 2012a).

The current study had several strengths. First, instruments with sound reliability and validity were utilized to collect the data. Second, the novelty of this study is that there are no researches that have sought to investigate the effects of intervention program in defensive actions. Despite the aforementioned strengths, the study results should be treated with some caution due to the utilization of a small sample, which limits the capacity to extrapolate the results. Future studies should be developed with a larger sample (that could minimize the effects of other factors on tactical development, especially when researching amateur players) and with teams of different age categories, gender, and levels of expertise to improve the understanding of this issue. On the other hand, the program has been carried out in natural context, where some contextual variables are difficult to control. In this sense, players' decision-making and execution could be affected by the contextual variables as outcome or current score (potentially affecting motivation and playing behaviors) (Lupo and Tessitore, 2016). In addition, due to the level of players (average skill level of sport expertise), we can hypothesize that a longer intervention program and more matches to verify the players' behaviors could be provided to make more solid results. Future research in this line is necessary to provide scientific knowledge and help coaches to improve their intervention programs and better control the learning process of players.

CONCLUSION

This study has shown evidence that the NLP approach is an appropriate theoretical framework to enhance acquisition of defensive tactical behavior in futsal. Our results come to reinforce that the use of numerical unbalance in defense promotes not only acute but also chronic effects in players' tactical behavior. Additionally, the variability of practice led to searching answers to different problems and always with actions. In this sense, despite of all the efforts of the coach in this program destined to unify the understanding and improvement of the attack, not keeping in mind the defensive phase, players improved their defensive tactical capability to perform (in marking, blocking, and help coverage). However, not all actions were improved. Specifically, marking action improvements are related with tasks with numerical advantage of the offensive team. However, if coaches want to improve interception actions, offensive numerical superiority tasks are not the best option. This study demonstrated the need for coaches to identify the development of defensive (or offensive) actions in small-sided games with duality of purposes. Therefore, these results provide practitioners with important insights on how they can better organize their training sessions and design representative tasks to optimally develop technical–tactical training processes based on the phases of futsal game.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Research Committee of a Spanish University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

DP developed data collection and wrote the first draft of the manuscript. AP, BT, and AM contributed to design of the study, data analysis and interpretation, and wrote sections of the manuscript. All authors contributed to manuscript revision, read and approved the submitted manuscript.

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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.

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REVIEW
published: 06 November 2020
doi: 10.3389/fpsyg.2020.569897

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

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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

OPEN ACCESS

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *05 June 2020*
Accepted: *30 September 2020*
Published: *06 November 2020*

Citation:
Spyrou K, Freitas TT, Marín-Cascales E and Alcaraz PE (2020) Physical and Physiological Match-Play Demands and Player Characteristics in Futsal: A Systematic Review. Front. Psychol. 11:569897. doi: 10.3389/fpsyg.2020.569897

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 ≥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.

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

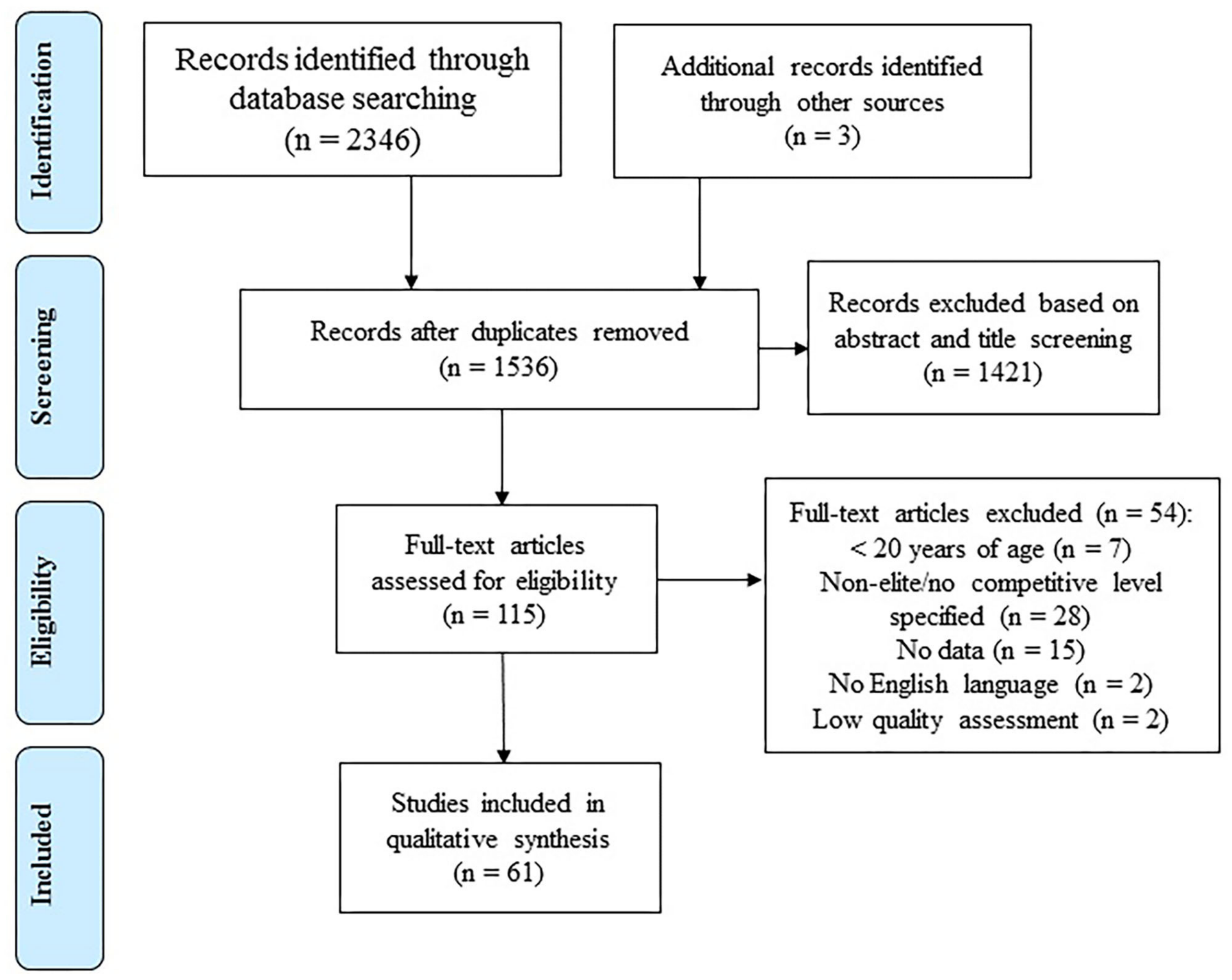

FIGURE 1 | Flow diagram.

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°)	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% ± 2[d]	NR	1232 m 28% ± 2.2[c]	571 m 13.7% ± 2.0[c]	348 m 8.9% ± 3.4[c]	4313 ± 2138
Bekris et al. (2020)	21	NR	93% ± 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% ± 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% ± 9.0[a] 43.7 ± 5.8[b] $ml \cdot kg^{-1} \cdot min^{-1}$ GL: 63.2% ± 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% ± 5.8[d] GL: 147 ± 7[d] $b \cdot min^{-1}$ 73.7% ± 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% ± 2[c]	11.3% ± 1.4[c]	12% ± 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

(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·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·L^{-1} (1st half) and 4.2 ± 2.2 mmol·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 (SlgA), 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 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 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} ($ml\cdot kg^{-1}\cdot min^{-1}$)	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 $km\cdot h^{-1}$	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 $km\cdot h^{-1}$	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 $km\cdot h^{-1}$ NMEL-G: 19.5 ± 0.6 $km\cdot h^{-1}$	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 $km\cdot h^{-1}$: 1.5 ± 0.4 12 $km\cdot h^{-1}$: 2.0 ± 0.6 14 $km\cdot h^{-1}$: 4.4 ± 1.2
Gorostiaga et al. (2009)	15	Elite	SRT	N/A	NR	13 $km\cdot h^{-1}$: 170.7 ± 8 14 $km\cdot h^{-1}$: 179.9 ± 6 15 $km\cdot h^{-1}$: 183.5 ± 5	NR	13 $km\cdot h^{-1}$: 4.2 ± 2.0 14 $km\cdot h^{-1}$: 6.4 ± 2.1 15 $km\cdot h^{-1}$: 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	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 $km \cdot h^{-1}$	NR	NR	NR	NR
Valladares-Rodriguez et al. (2017)	13	Elite	30-15 IFT	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 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; 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	$60° \cdot s^{-1}$ (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 $m \cdot s^{-1}$ 10 m: 5.68 ± 0.19 $m \cdot s^{-1}$ 20 m: 6.61 ± 0.22 $m \cdot s^{-1}$	Zig-zag (100°): 3.52 ± 0.11 $m \cdot s^{-1}$
Loturco et al. (2020)	62	Elite	NR	NR	5 m: 4.79 ± 0.22 $m \cdot s^{-1}$ 10 m: 5.67 ± 0.23 $m \cdot s^{-1}$ 20 m: 6.62 ± 0.25 $m \cdot s^{-1}$	Zig-zag (100°): 3.52 ± 0.16 $m \cdot s^{-1}$ COD-Def zig-zag (100°): 3.09 ± 0.25 $m \cdot s^{-1}$
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	NR	NR	NR
			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			
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	NR	NR	NR
			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			

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.

FUNDING

This study was financed by PMAFI-COVID19/09 UCAM, Murcia, Spain.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.569897/full#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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 26 November 2020
doi: 10.3389/fpsyg.2020.584602

Pre-match Warm-Up Dynamics and Workload in Elite Futsal

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Warming up prior to competition is a widely accepted strategy to increase players' readiness and achieve high performances. However, pre-match routines are commonly based on empirical knowledge and strongly influenced by models emerging from elite team practices. The aim of the present study was to identify and analyze current pre-match warm-up practices in elite futsal. Forty-three elite players were analyzed during their pre-match warm-up routines during the Portuguese Futsal Cup Final 8. Warm-up tasks were classified according to duration, type of activity, sequence, and structure. External load variables included the total distance covered, total distance covered per minute, running distance per minute, sprinting distance per minute, number of accelerations per minute, and number of decelerations per minute. Results highlighted that warm-up routines lasted for 27.5 ± 9.2 min and included nine major different tasks. Open-skill activities were prioritized by coaches; competitive and non-competitive futsal-specific tasks were included in 90% of the total warm-up routines, with higher focus on non-competitive tasks (68% of total time). The intensity progressively increased during warm-ups, mainly because of the higher number of accelerations and decelerations per minute. Pre-match warm-up routines strongly endorse futsal-specific and representative tasks in order to establish pre-match settings able to prepare players for the upcoming game. When designing pre-match warm-up routines, coaches should be aware that duration, sequence, and type of tasks may affect players' acute performance and readiness.

Keywords: potentiation, performance enhancement, priming methods, current practices, warm-up structure

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *17 July 2020*
Accepted: *29 October 2020*
Published: *26 November 2020*

Citation:
Silva N, Travassos B, Gonçalves B, Brito J and Abade E (2020) Pre-match Warm-Up Dynamics and Workload in Elite Futsal. Front. Psychol. 11:584602. doi: 10.3389/fpsyg.2020.584602

INTRODUCTION

Futsal is a complex and dynamic team sport requiring players to combine decision-making processes and intermittent high-intensity actions such as sprints and changes of direction (Barbero-Alvarez et al., 2008). Futsal players cover more than 25% of the distance at high speed or sprinting with a work-to-rest ratio of 1:1 (Barbero-Alvarez et al., 2008) and repeated sprint blocks of two to three sprints interspersed by 15-s intervals (Caetano et al., 2015). Pre-match warm-up plays an important role in order to help players to cope with these demands and support acute performance potentiation. In fact, warm-up routines are known to promote temperature, metabolic, psychological, and neuromuscular mechanisms (McGowan et al., 2015) that may be key to improve players' readiness and potentiate neuromuscular performance before training or competition.

Under the scope of performance potentiation, neuromuscular function appears to be acutely increased when preceded by maximal or submaximal efforts (Wilson et al., 2013), a phenomenon known as post-activation potentiation (PAP). PAP is strongly related to the enhanced central activity of the motor neurons (Tillin and Bishop, 2009), spinal cord reflex activity, and phosphorylation of the myosin chain (Smith and Fry, 2007), which leads to an increase in the sensitivity of the myofilaments to $Ca2^{+}$ (MacIntosh, 2003). Recently, a new concept of PAP has been proposed in order to be more convergent with the timeline of peak voluntary performance enhancement. Thus, post-activation performance enhancement (PAPE) occurs when a high-intensity voluntary conditioning contraction leads to enhancement of subsequent involuntary muscular performance without confirmatory evidence of classical PAP (Cuenca-Fernandez et al., 2017).

Post-activation performance enhancement effect can be explained with the increase of muscle temperature, fiber water content, and activation, but inhibited by residual fatigue and motor pattern interference (Blazevich and Babault, 2019), which means that its effectiveness depends on the balance between potentiation and fatigue (Tillin and Bishop, 2009). The mechanisms underlying the warm-up are well aligned with the PAPE effects and should be taken in consideration when designing a warm-up routine.

Active warm-up routines are commonly used as a strategy for pre-competition preparation in team sports, generally including a wide variety of closed and open skills to improve key abilities such as speed, change of direction speed, vertical jump, and reactive agility performance (Gabbett et al., 2008). Under this scope, exercises such as small-sided games (SSG) and shooting exercises are often proposed by coaches. These exercises can potentially boost performance through priming neural pathways and increased neuromuscular activation while maintaining a link to technical and tactical components (McGowan et al., 2015). Other activities such as sprinting and stretching are also commonly used in warm-up routines (Ayala et al., 2012). Nevertheless, a stronger consensus is missing regarding the effects, moment, and type of sprinting and stretching (Guinoubi et al., 2015; van den Tillaar and von Heimburg, 2016).

When designing a warm-up routine, coaches should take into consideration several factors such as duration and total volume, intensity, sequence, and the dynamics of the selected exercises. In team sports, the warm-up is frequently performed over an extended period of time (>20 min), which may promote fatigue and inhibit performance enhancements (Silva et al., 2018). Even though a shorter warm-up appear to have similar benefits as a longer warm-up (Mujika et al., 2012; van den Tillaar and von Heimburg, 2016), some players report the need for longer warm-up periods to feel psychologically prepared for competition (Yanci et al., 2019).

Regardless of exercise sequence, the warm-up should progress in intensity, preparing for the specific tasks of the sport, and finishing with tasks of maximum intensity (Silva et al., 2018). However, it is also suggested that short-term explosive exercises such as sprinting and jumping may benefit from high-intensity warming up with an appropriate recovery so that the athlete is able to produce high levels of strength early in a team sports game (Anderson et al., 2014). Thus, the main challenge seems to be the identification of appropriate exercises and sequence capable of promoting the ideal intensity and recovery.

Despite the importance of structure and dynamics of warm-up in team sports, exercises are still being selected based on empirical knowledge and might be strongly influenced by observations on routines conducted by high-level teams. Thus, understanding warm-up routines in elite teams might provide key hints to develop evidence-based warm-up routines with great ecological value. To the best of our knowledge, and despite some theoretical proposals, there is no research focused on the analysis of warm-up structure and intensity in futsal. Thus, the aims of this study were to identify current pre-match warm-up practices in elite futsal teams and to analyze its dynamics and workload.

MATERIALS AND METHODS

Participants

Forty-three elite male futsal players from six different futsal elite teams participated in this study. Data were collected during a futsal major event—Final 8 of the Portuguese Futsal Cup. The event lasted for 4 days during the in-season period (May 2019). Goalkeeper (GK) data were excluded due to the specificity of goalkeeping role and warm-up routine. All players, coaches, and clubs were informed about the study design, requirements, and procedures, and their consent was obtained. The study protocol was approved by the local Ethics Committee of Universidade da Beira Interior (CE-UBI-Pj-2018-029) and follows the recommendations of the Declaration of Helsinki. To ensure player confidentiality, all data were anonymized prior to analysis.

Procedures

As warm-up routines in futsal included several exercises, they were aggregated under specific categories according to their characteristics (**Figure 1**). This classification was made by two experts (UEFA A level) with more than 10 years of experience. They individually classified each exercise and if an agreement was not reached, exercises were reviewed and classified accordingly. In particular cases, due to the lack of specific nomenclature reported by literature, the experts' classification was considered to create specific and reliable categorization. The exercises were classified as (i) Closed Skills—Mobility Exercises (general warm-up exercises of sub-maximal aerobic intensity in order to increase muscle temperature, including jogging, running, skipping forward and backward, and plyometric exercises); (ii) Closed Skills—Stretching (differencing static and dynamic stretching exercises); (iii) Closed Skills—Sprinting (considered by different distances of the sprinting activity after visual or audio signal from the coach with two different areas, i.e., 10- and 20-m distance); (iv) Open Skills—Futsal-Specific Skills without Opposition (technical–tactical exercises without opposition to improve specific technical futsal skills; different passing situations

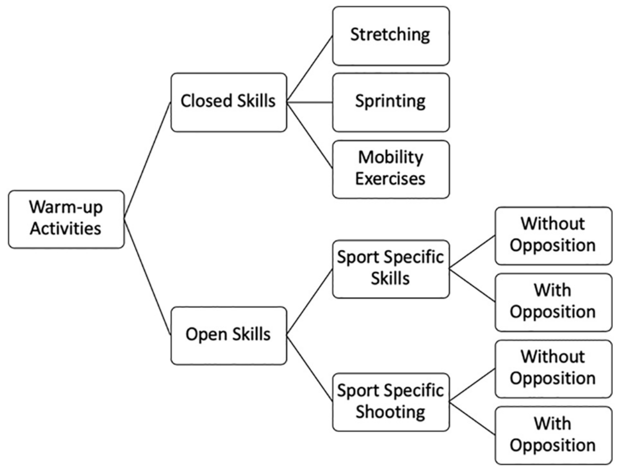

FIGURE 1 | Classification of exercises under specific categories according to their characteristics.

were considered using diverse distances between players and distinguishing exercises with two or three players); (v) Open Skills—Futsal-Specific Skills with Opposition (technical–tactical exercises such as rondos and SSG; exercises were considered according to changes in space and number of players); (vi) Open Skills—Futsal-Specific Shooting without Opposition (individual or two-player combinations for shooting and tactical combinations with three or four players in a progressive pattern till shooting action); and (vii) Open Skills—Futsal-Specific Shooting with Opposition (exercises of counterattack and offensive–defensive transition; different numerical relations were created between attackers and defenders, e.g., $2 \times 1 + GK$; $3 \times 1 + GK$; $3 \times 2 + GK$).

A non-experimental descriptive design was used to record and register the external load of players during warm-up routines before official futsal matches. Players' activity was assessed using inertial measurement units (IMU) with ultra-wideband tracking system technology (WIMU PRO^{TM}, RealTrack Systems, Almeria, Spain). The sampling frequency for the positioning system was 20 Hz. The devices were turned on 10–15 min before the warm-up began. They were placed on players with a specific custom neoprene vest (Svilar et al., 2019). The system has six ultra-wideband antennas, placed 4 m outside the court. The system operates using triangulations between the antennas and the units and derives the unit position (X and Y coordinates) using one of the antennas as a reference. Data were analyzed using SPRO Software (RealTrack Systems, Almeria, Spain). The accuracy and reliability of these devices have been previously reported and validated (Pino-Ortega et al., 2018; Hernandez-Belmonte et al., 2019).

Descriptive Characteristics

In order to characterize the warm-up routine, the following variables were analyzed: (a) total duration of the warm-up, (b) duration of different categories, (c) number of warm-up categories, (d) sequence of tasks, (e) number of exercises, and (f) exercises used in each category. To analyze the workload demands of warm-up categories, the following external load variables were calculated: total distance covered (m), total distance covered per minute, running distance per minute (12–18 km/h), sprinting distance per minute (>18 km/h), number of accelerations per minute (>2 m/s^2), and number of decelerations per minute (<-2 m/s^2).

Data Analysis

A description of warm-up tasks and its sequence was performed using mean, standard deviations, and percentage of use of each warm-up task in each warm-up and its order over the warm-up. Every variable analyzed through non-parametric comparisons is reported by median and range in the text or in a table.

To characterize the pre-match warm-up workloads, a Shapiro–Wilk test was used to assess the normal distribution of data. Due to the existence of non-normal distribution of data, the differences between warm-up tasks were assessed using the Kruskal–Wallis test and the Dwass-Steel-Critchlow-Fligner to pairwise comparisons. To characterize the warm-up workload profile of each exercise in the same category, individual exercises external load variables were compared with Mann–Whitney *U* test.

Finally, a discriminant analysis was used on the workload indicators (dependent variables) from the warm-up tasks (independent variables) to create a function that classifies the tasks as accurately as possible. Three discriminant functions were obtained and interpreted based on the examination of structure coefficients (SC) greater than $|0.30|$ (Tabachnick and Fidell, 2007). The statistical specifications of the model included (i) the eigenvalues that show the canonical correlation, whose value (between 0 and 1) indicates to what extent the discriminant variables make it possible to differentiate among the task categories; (ii) Wilks' Lambda, which expresses the total variability proportion not due to the differences among the task categories; (iii) group centroids that show the location of the task categories in each of the discriminant functions, making it possible to see if they are located, on average, in the positive or negative scores of the function; (iv) the SCs determine the correlation of the variables with the discriminant functions, those of the first function being the ones with the greatest discriminative capacity (the larger the magnitude of the coefficients, the greater the contribution of that variable to the discriminant function, showing the ones that contribute most to discriminating from the value $\geq |0.30|$).

Statistical analyses were performed using IBM SPSS for Windows statistics, version 22.0 (IBM Corp., Armonk, NY, United States).

RESULTS

Description of Warm-Up Tasks and Its Sequence

The mean warm-up routine duration was 27.5 ± 9.2 min, ranging from 18 to 50 min. Only 20% of warm-up routines lasted 15–20 min. The mean total number of warm-up

TABLE 1 | Description of task categories, duration, % of occurrence, and number of exercises in each category.

Activity	Duration (min)	Warm-up	Exercises (*n*)
Closed skills			
Stretching	2.0 ± 0.67	70%	1.6 ± 0.5
Sprinting	1.1 ± 0.7	80%	1.3 ± 0.5
Mobility exercises	3.5 ± 1.32	30%	3.0 ± 1.7
Sub-total	1.9 ± 1.2		1.7 ± 1.0
Open skills			
Futsal-specific skills without opposition	7.4 ± 5.43	90%	2.0 ± 0.9
Futsal-specific skills with opposition	4.9 ± 2.5	100%	1.2 ± 0.4
Futsal-specific shooting without opposition	8.4 ± 2.3	100%	2.6 ± 0.7
Futsal-specific shooting with opposition	4.0 ± 2.01	90%	1.7 ± 0.7
Sub-total	6.2 ± 3.7		1.8 ± 0.9

Duration – mean duration in minutes of each activity; warm-up – percentage of the presence each activity in the studied warm-up routines; Number of exercises – number of exercises in each category.

TABLE 2 | Sequence and percentage of activities occurred at the beginning, middle, or final phase of the warm-up.

Activity	Sequence	Percentage of activity in part of the warm-up
Stretching	Beginning	57%
	Middle	29%
	Final	14%
Sprinting	Beginning	0%
	Middle	0%
	Final	100%
Futsal-specific skill without opposition	Beginning	100%
	Middle	0%
	Final	0%
Futsal-specific skill with opposition	Beginning	40%
	Middle	60%
	Final	0%
Futsal-specific shooting without opposition	Beginning	0%
	Middle	40%
	Final	60%
Futsal-specific shooting with opposition	Beginning	0%
	Middle	10%
	Final	90%

exercises was 9.3 ± 1.8, and mostly comprising open-skill tasks (80% of total exercises). Open skills were the mostly used, particularly exercises without opposition (more than 50% of the mean time of total warm-up routines). Tasks with opposition (SSG or Counterattacks) were also meaningful. Closed-skill tasks were the least used and were also shorter in duration (see **Table 1**).

Sport-specific shooting tasks without opposition were the longest exercises with nearly 8.5 min and included three exercises (individual shooting, two-player combinations or set pieces shooting, and tactical combinations). Such exercises were observed in all warm-up routines. The priority given to futsal-specific activities was noticeable because skill activities with and without opposition as well as futsal shooting activities, such as counter attacks, were a key part of the warm-up routine with a mean total of 7.5, 5.0, and 4.0 min, respectively. All of these tasks were observed in 90% of warm-up routines.

The shortest exercises were closed-skill tasks such as stretching and sprinting. Stretching exercises lasted for approximately 2 min. Static stretching was the most used activity with 67% of the total stretching time. Finally, sprinting tasks lasted 1.1 ± 0.7 min, and 90% of this activity was performed in a 10-m space with players responding to acoustic or visual stimulus. In some cases, these sprints were combined with changes of direction.

After analyzing the sequence of tasks, a generic pre-match warm-up routine sequence emerged through the identification of patterns on the use of warm-up categories. Stretching tasks were mainly performed in the beginning of the warm-up. Regarding open-skill tasks, futsal-specific skills were performed before futsal-specific shooting. In both categories, warm-up evolved from tasks without opposition to tasks with opposition (i.e., SSG or counterattacks with different numerical relationships). All sprinting tasks were performed in the final of the warm-up routine (see **Table 2**).

Characterization of Warm-Up Workload

Considering the warm-up categories, mobility exercises revealed the highest amount of distance covered per minute (a median of 83 with a range of 35.6–105 m/min) followed by tasks that involved shooting exercises with or without opposition (65 ranging from 23.4 to 104 m/min, and 63.9 ranging from 40.7 to 113 m/min). Sport-specific skill and sprinting tasks revealed lower values of distance covered per minute than mobility and shooting exercises. The least demanded activity of distance covered per minute was stretching (12.3, ranging from 1.12 to 64.1 m) (see **Figure 2**).

The running distance per minute achieved the higher values in sport-specific shooting and sprinting tasks, with values ranging from 0 to 27.6 with a median of 8.54 and 0–23.6 with a median of 7.56 m/min, respectively. Sport-specific skill and mobility exercise tasks showed the lowest distances covered. Stretching exercises did not consider any activity that involved higher speed thresholds than running and sprinting.

Tasks with opposition, regardless of being skill- or shooting-oriented, sprinting tasks, and mobility exercises were the most demanding regarding the number of accelerations and decelerations per minute. As verified in other external load variables, stretching exercises were the least demanding. In all tasks, the number of accelerations was higher than decelerations (see **Table 3**).

Summarizing, mobility exercises, sprinting tasks, and shooting tasks revealed higher values of distance covered per minute at higher speed thresholds than skill tasks as well as the number of accelerations and decelerations per minute. Stretching exercises were the least demanding exercises in all external load variables considered in this study.

Warm-Up Workload Profile

Looking to the data obtained for all variables, the warm-up model slightly changed between variables through warm-up duration, although an overall consistent trend was still observed. Total

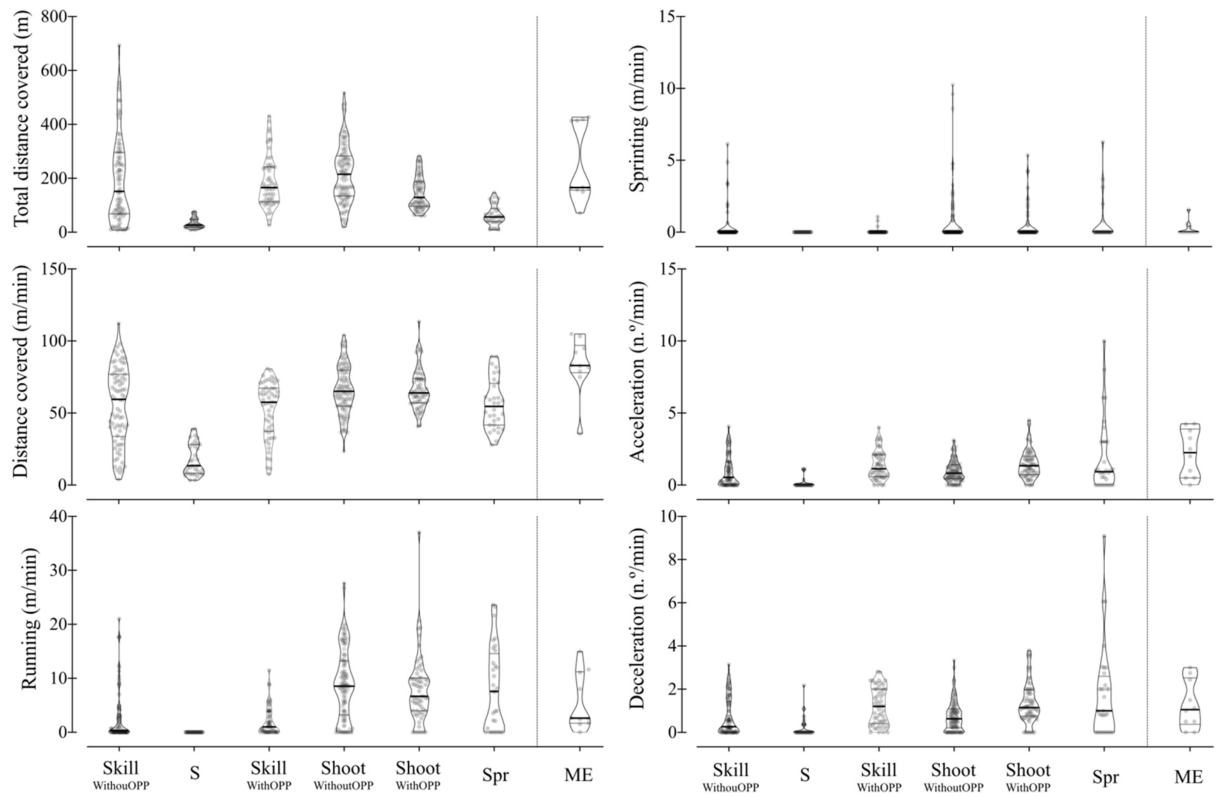

FIGURE 2 | Violin plots of the descriptive analysis. Medium horizontal line represents the median. The lower and upper horizontal lines correspond to the first and third quartiles (the 25th and 75th percentiles). SkillWithouOPP, skill without opposition; S, stretching; SkillWithOPP, skill with opposition; Shoot WithoutOPP, shooting without opposition; ShootWithOPP, shooting with opposition; Spr, sprinting; ME, mobility exercises.

TABLE 3 | Descriptive analysis of each activity.

Variables	Total distance covered (m)			Distance covered (m/min)			Running (m/min)			Sprinting (m/min)			Accelerations (n/min)			Decelerations (n/min)		
	Median	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**	**Median**	**Min**	**Max**
Skill$_{WithoutOPP}$	231	8.4	431	61.4	10.2	92.8	0.7	0	21	0	0	6.1	0.9	0	4.1	0.6	0	3.1
Stretching	13.4	1.1	68.4	12.3	1.1	64.1	0	0	0	0	0	0	0	0	3	0	0	2.2
Skill$_{WithOPP}$	166	26.8	283	57.5	7.7	80.7	0.9	0	11.5	0	0	1.1	1.1	0	4	1.2	0	2.8
Shoot$_{WithouOPP}$	215	19.4	517	65	23.4	104	8.5	0	27.6	0	0	10.3	0.8	0	3.1	0.7	0	3.3
Shoot$_{WithOPP}$	129	61	283	63.9	40.7	113	6.7	0	37	0	0	5.4	1.3	0	4.5	1.2	0	3.8
Sprinting	56.7	9.2	147	54.6	27.9	89.2	7.6	0	23.6	0	0	6.3	0.9	0	10	1	0	9.1
Mobility exercises	166	71.3	427	83	35.6	105	2.2	0	15	0	0	1.6	2.3	0	4.2	1.1	0	3

distance covered and distance covered per minute had a non-linear profile with the first half of the warm-up having similar distances covered interspersed with the lowest value of the all warm-up and there was a decrease in the final two tasks. When analyzing distance covered at different speed zones, a slight difference was observed between running and sprinting. At the end of the warm-up, shooting exercises with opposition and sprinting tasks showed a lower median value than the previous activity, but with considerable number of players with highest values than in previous activity. Acceleration and deceleration profiles were consistent with an undulatory pattern throughout the duration of the warm-up and ending with a rising number of actions of high intensity.

When applied with a more pronounced analysis, taking into consideration some formal exercise variables such as number of players, space, and dynamics in each category, some key tendencies emerged. Regarding skill without opposition, it was observed that passing exercises with three players revealed significant higher values in sprinting ($p = 0.011$) when compared to two players. Sprinting exercises performed in 20 m demanded a higher running distance from players ($p = 0.034$) in opposition to a lower number of decelerations than 10-m sprinting ($p = 0.02$).

TABLE 4 | Warm-up load demands profile in each warm-up category compared with Mann–Whitney *U* test.

Variables		Total distance covered (m)			Distance covered (m/min)			Running (m/min)			Sprinting (m/min)			Accelerations (n/min)			Decelerations (n/min)		
		Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Skill$_{WithoutOPP}$	Pass 2 ply	193	19	326	52.9	25.4	92.8	0.43	0	11.3	0	0	0	1	0	3.43	1	0	3.14
	Pass 3 ply	253	8.36	693	66.1	10.2	90.5	1.92	0	21	0	0	6.13	0.8	0	4.06	0.29	0	2.4
	P	0.129			0.551			0.109			**0.011**			0.67			0.088		
Stretching	Dynamic	26.3	5.8	68.4	17.5	3.5	64.1	0	0	0	0	0	0	0	0	3	0	0	2
	Static	13	1.12	41	8.93	1.12	38.6	0	0	0	0	0	0	0	0	1.09	0	0	2.17
	P	**0.035**			**0.002**			n.a.			n.a.			**0.044**			**0.013**		
Skill$_{WithOPP}$	SSG	239	109	431	67.3	54.6	80.7	3.54	0	11.5	0	0	1.08	1.41	0	3.33	1.4	0	2.82
	Rondo	140	26.8	277	38.9	7.67	71.3	0	0	8.8	0	0	0.79	0.89	0	4	1.04	0	2.4
	P	**<0.001**			**<0.001**			**<0.001**			0.443			0.682			0.329		
Shoot$_{WithouOPP}$	Combinations	216	19.4	517	63.2	23.4	104	8.46	0	20	0	0	9.61	0.76	0	3.12	0.6	0	2.41
	Tactical	199	68.7	361	72.6	45.8	99.4	12.7	0	27.6	0.83	0	10.3	1	0	2.67	0.72	0	3.34
	P	0.986			0.085			**0.019**			**<0.001**			0.255			0.282		
Shoot$_{WithOPP}$	2 attackers	120	61	283	64.8	40.7	113	6.3	0	37	0	0	5.36	1.07	0	3.18	1.06	0	3
	3 attackers	134	83.1	225	63	41.5	83.3	8.39	0	16.1	0	0	4.19	1.81	0	4.5	1.52	0	3.79
	P	0.781			0.277			0.598			0.346			**0.023**			**0.03**		
Sprinting	10 m	58.7	9.22	147	58.9	27.9	89.2	3.92	0	23.6	0	0	3.13	1.05	0	10	2	0	9.09
	20 m	56.3	48.7	66.6	48.1	41.6	56.9	16.5	0	23.2	0	0	6.26	0.855	0	0.855	0	0	0.855
	P	0.906			0.331			**0.034**			0.136			0.135			**0.02**		

Pass 2 ply, passing exercises between 2 players; Pass 3 ply, passing exercises between 3 players with movement; SSG, small sided games with different formats; rondo, competitive exercises with one or two defenders with limited movements; combinations, two or three players shooting combinations; tactical, tactical shooting pattern with progression; 2 attackers, counterattack situations with 2 attackers; 3 attackers, counterattack situations with 3 attackers. Bold values represent p < 0.05.

Elite futsal teams used SSG and rondos under the sport-specific skill exercises with opposition. SSG were the most demanding in all running variables ($p < 0.001$ for all variables), with the exception of sprinting distance, while maintaining a coherent profile regarding the number of accelerations and decelerations.

Breaking down sport-specific shooting exercises without opposition, it was possible to identify that tactical combination exercises were most demanding in distance covered at higher thresholds (>18 km/h) ($p = 0.019$ and $p < 0.001$).

Counterattacks were part of 90% of the warm-up routine and coaches used two different strategies with two or three attackers. Three-attacker counterattack exercises ($3 \times 2 + GK$ or $3 \times 1 + GK$) recorded a significant higher number of accelerations and decelerations ($p = 0.023$ and $p = 0.03$, respectively) (see **Table 4**).

Dynamics of Each Activity Category

The discriminant analysis revealed differences in the characteristics of each warm-up category. The summary of discriminant functions showed that the first function explained ∼51% of the data variability, while the second explained ∼30% and the third explained ∼16% (see **Table 5**). Based on the structure coefficients $>|0.30|$, the first function is determined by all variables, with the exception of number of decelerations, while the second function confirms the high correlation between running and sprinting distance. The first function allows to differentiate the stretching tasks from the other categories due to the low values recorded in all variables followed by skill tasks ending with mobility exercises recording the higher value. The second function discriminates between sprinting tasks and shooting with opposition tasks from the rest of the warm-up categories, highlighting the low values of the discriminant variables of this function, namely, running and sprinting distance per minute.

The territorial map of the discriminant functions allows one to observe that closed-skill tasks had a more convergent behavior with a low number of values away from the group centroid than open-skill tasks. Also, skill exercises were more similar to each other than shooting exercises regardless of the existence of opposition (see **Figure 3**).

DISCUSSION

This study aimed to identify the dynamics and structure of warm-up routines in elite futsal. From this analysis, type, duration, intensity, sequence, and structure of the tasks emerged as key variables that should be discussed under a combined scope of evidence-based practice and real-world performance enhancement strategies.

Even though natural differences were observed within teams' WU, a global and coherent warm-up model emerges from the data recorded. Sport-specific skills without opposition and static stretching exercises are globally used as primary warm-up exercises with a total duration closer to 9 1/2 min. Following that, teams tend to prioritize 5 min of sport-specific skill exercises

TABLE 5 | Summary of discriminant functions.

Variables	Function 1	Function 2	Function 3
Eigenvalues			
Eigenvalue	0.605	0.360	0.195
% of Variance	50.9	30.2	16.4
Cumulative%	50.9	81.1	97.5
Wilks' Lambda	0.373	0.598	0.813
Chi-square	374.708	195.200	78.639
Significance	<0.001	<0.001	<0.001
Structure coefficients			
Total distance covered (m)	**0.937***	0.277	0.137
Distance covered (m/min)	**0.674***	−0.188	**−0.601***
Running (m/min)	**0.406***	**0.797***	0.058
Sprinting (m/min)	**0.312***	**−0.391***	**0.557***
Accelerations (n/min)	**0.352***	−0.232	**0.585***
Decelerations (n/min)	0.193	−0.001	−0.257
Functions at group centroids			
Stretching	−2.049	−0.484	−0.464
Sprinting	0.351	−1.496	0.227
Mobility exercises	1.073	0.581	0.984
Sport-specific skill without opposition	−0.336	0.517	0.227
Sport-specific skill with opposition	−0.421	0.270	0.636
Sport-specific shooting without opposition	0.483	0.319	−0.504
Sport-specific shooting with opposition	0.642	−0.517	0.072

**SC discriminant value ≥ |0.30| .*

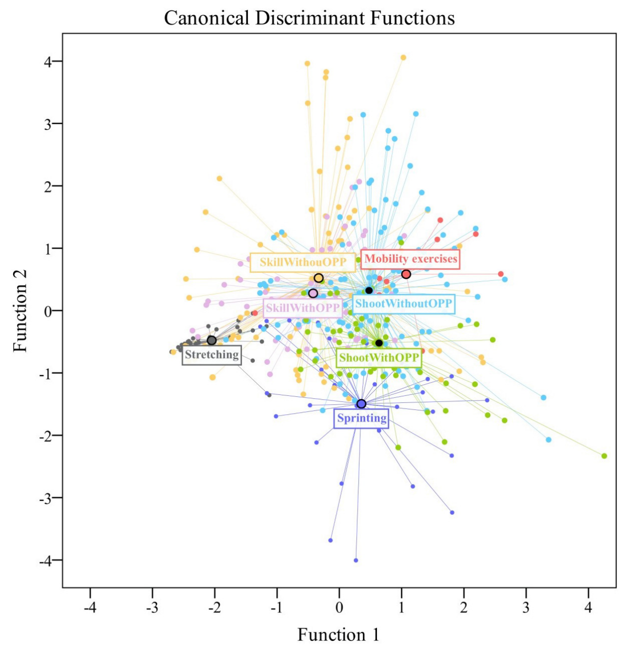

FIGURE 3 | Territorial map of discriminant functions for the task categories of the elite warm-up.

with opposition such as SSG or rondos with different area and numerical relations that precede sport-specific shooting exercises. These routines typically progress from no-opposition (i.e., tactical combinations, individual shooting and set pieces, ≈8 1/2 min) to game-like situations (i.e., counterattacks of different numerical relations between attackers and defenders gradually increasing the number of players, ≈4 min). Repeated sprinting exercises such as 10-m linear accelerations and with changes of direction are systematically used to close WU. This warm-up model lasts for 27 1/2 and includes 11 exercises grouped under different categories with special emphasis on open skills with important ecological value to match performance.

The specific skill tasks displayed important game-related contextualized situations to promote a strong link and transference effect to match performance. Under this scope, coaches designed shooting exercises replicating positional attack patterns, set pieces, and counterattacks that seem to be the most decisive phases of the game in order to score (Sarmento et al., 2018; Mendez et al., 2019). Remarkably, shooting exercises with no opposition are representative of the most important shooting situations in futsal (Sarmento et al., 2016), such as two-player combinations, set pieces shooting, and even specific tactical combinations (Leite, 2012). This ability to replicate offensive situations during positional attack is also enhanced through skill exercises that included key technical actions like passing, receiving, and driving the ball. Skill tasks with opposition are also determinant to create game-like situations where players may improve their adaptability and variability to competitive situations in rondos or SSG (Mendez et al., 2019).

Static stretching was used by the majority of the teams. In fact, it seems to be a common practice in team sports WUs, even though it is an equivocal evidence-based practice. Although static stretching effects on muscle power and strength has been shown to be trivial or even detrimental to subsequent performance (McGowan et al., 2015), the present investigation showed that 67% of the total stretching exercises were dedicated to static routines. It is important to notice that this strategy may compromise acute potentiation, especially if performed for a long period of time (Pojskic et al., 2015a,b; Jamshidi et al., 2016). Even if the use of short periods of static stretching appears to be trivial to subsequent performance (Blazevich et al., 2018), choosing dynamic stretching seems to be a more adequate option because of the higher transfer effect to performance, especially in high-elite athletes (Chaabene et al., 2019).

Sprinting tasks were also frequently used by coaches in warm-up including visual and/or acoustic signals on intermittent sprinting bouts of 10–20 m distance. This option seems to potentiate subsequent sprint performance, particularly when performed at the end of the warm-up (Guinoubi et al., 2015; van den Tillaar and von Heimburg, 2016). These effects may be explained by the PAPE effect as it is expected that high-intensity actions activate temperature and metabolic mechanisms that enhance subsequent performance (Blazevich and Babault, 2019).

It should be expected that these exercises would stand out on external load data; however, exercises with higher sprinting distance covered per minute emerged. It is important to notice that 20-m sprints allowed players to reach a sprinting threshold while 10-m bouts highlighted the number of accelerations and decelerations. Taking into consideration these results, it seems more appropriate to perform sprinting exercises in 10- and 20-m spaces in order to let players achieve the desired sprinting actions without compromising accelerations and decelerations.

Interestingly, data of the present investigation show that the mean total duration of the warm-up was twice that suggested by recent studies, with none of the 10 WUs being performed within the referenced time window. Shorter WUs appear to be more effective for sprint performance enhancement than longer warm-up routines (Yanci et al., 2019). In fact, a recent review advices a total warm-up duration of 10–15 min to have an acute positive effect on muscle temperature and subsequent physical performance (Silva et al., 2018). These results may be particularly relevant due to the necessary balance between potentiation and fatigue induced by warm-up exercises. The desired acute enhancement of player performance is highly associated with the increase of temperature (McGowan et al., 2015) that occurs in the first 3–5 min of warm-up and plateaus after a 10–20-min interval (Bishop, 2003). Not compromising this positive effect is key to performing under the previously mentioned time frame to prevent muscle glycogen depletion and guarantee heat-storage capacity (Bishop, 2003).

After analyzing the duration of different tasks, it is possible to understand that coaches prioritized open skills rather than closed skills. This pattern could be explained by the methodological paradigm of futsal coaches and the positive effects of the use of specific exercises in short-time performance. In the past years, a methodological approach has emerged that integrates all performance factors with warm-up exercises that combine physical demands with a technical and tactical purpose in order to create a pre-match setting with the upcoming match context where the theoretical referential supports this decision; thus, the use of open-skill tasks has shown to be equally effective as closed-skill tasks in key abilities in team sports, namely, futsal, such as sprinting, change of direction, and reactive agility performance (Gabbett et al., 2008). Furthermore, it appears that the use of specific tasks can have an added neuromuscular activation, further ergogenic benefits (Bishop, 2003; Andrade et al., 2015), and high ecological value. However, coaches should be aware that open-skill exercises promote larger individual variability than closed-skill exercises. The chaotic and unpredictable nature of game-like situations where movement patterns and external load applied to players are dependent of all performance factors could drive coaches to have specific closed-skill tasks to ensure that every player reaches an appropriate readiness condition in the end of the warm-up routine.

The warm-up intensity is strongly linked to its total duration and task sequence and structure. It is suggested that warm-up intensity above the anaerobic threshold (i.e., 90% of HRmax and an RPE of at least 16) may have positive effects in sprint performance, possibly up to 10 min (Anderson et al., 2014). An ecological interpretation of warm-up intensity should consider the load imposed to players under the scope of physiological (kinetic energy from distance covered at different speeds) and biomechanical demands (number of accelerations and decelerations) of each activity (Vanrenterghem et al., 2017). Also, warm-up demands should be analyzed under an integrative and ecological approach to evaluate real match context representativeness (Bradley and Ade, 2018). The first pattern that emerges is that shooting exercises are physiologically more demanding than skill exercises, which can be explained by the fact that shooting exercises demand more dynamic actions to progress until the shooting situation that itself involves high-speed actions unlike skill exercises that are designed to highlight technical actions with limited player possibilities. From a biomechanical load standpoint, there is a more balanced profile between all exercises but with three different levels. Exercises without opposition recorded a lower value of accelerations and decelerations than exercises with opposition, independently of their context, highlighting that being in a competitive task can have more influence to the goal of each activity due to high-intensity actions needed to beat the opposition. The number of accelerations is greater than decelerations in all tasks, a pattern that is in contrast to the literature (Harper et al., 2019) but can be explained by the intermittent nature of most warm-up exercises, and this trend could be key to protect players from the negative outcomes associated to decelerations. Closed-skill tasks presented an expected demand from the physiological and biomechanical perspective with sprinting exercises being in the more demanding group and stretching being the less demanding of all tasks.

The sequence of tasks should allow the desired players' performance enhancement to the upcoming match, but this analysis is not simple due to the scarcity of warm-up studies in team sports with real-world scenarios. It is possible, though, to claim that a warm-up routine should have a progressively intense ending with high-intensity actions such as sprints (Silva et al., 2018) in order to improve neuromuscular readiness. The physiological load has a mixed pattern because the first half of the warm-up shows a slight downward tendency increased by the presence of the stretching activity. In the second half of the warm-up routine, there is the increase of the intensity, but the final minutes are less demanding, which may limit the PAPE effect (Cuenca-Fernandez et al., 2017) that is desired with the high-intensity actions in the end of the WU. The biomechanical load has a more continuous pattern with a crescent demand through the warm-up routine with the exception of the stretching tasks placed in the beginning of the warm-up and the characteristics of the shooting tasks without opposition. However, these loading profiles seem to be more coherent with the literature and coaches should take this into consideration to achieve the desired effect.

Even though in this study tasks with similar features were coupled under the same category, it is important to notice that each category includes different exercises that could impose different demands and modify loading profiles previously analyzed. We must always look through an integrative magnifying glass where players' actions have a tactical context where they emerge and formal variable manipulation should lead to the desired effect. Under this scope, the area of the task can be manipulated with different results. Twenty-meter sprint tasks have revealed to be physiologically more demanding and should be prioritized with some previous high-intensity actions in order to cause the desired PAPE effect. In the shooting tasks without opposition, tactical combination exercises were most demanding, and these results may be linked to the increased area that players have to explore and consequent higher physiological demands (Sarmento et al., 2018). Additionally, tactical combinations demand that players cover a 20 × 20 m area with the continuity of every phase of the match—construction of offensive actions, finishing situations, and shooting instead of only the last phases that make up shooting combinations. The use of sport-specific skill exercises with opposition, namely, SSG, is a common practice in team sports warm-up routines (McGowan et al., 2015) due to its benefits from the neuromuscular point of view but also for tactical and technical upgrade regarding closed-skill tasks (Dello Iacono et al., 2019). The use of SSG should be prioritized relatively to rondos due to the lower physiological and biomechanical load of these tasks, and these exercises should maintain the increase of players, demands in preparation for the final part of the WU, but without compromising total duration of warm-up (Zois et al., 2011).

When confronting data recorded from elite futsal warm-up routines with the existing literature, important information emerges that may be carefully analyzed and interpreted in order to build key practical applications for coaches and practitioners. Coaches should be aware that shorter WUs with progressive increased intensity may be optimum to potentiate acute performance. For that purpose, coaches should review the abusive use of static stretching, opting for dynamic and sprinting exercises that should allow players to increase the number of high-intensity running in the final moments of the WU. The balance between open- and closed-skill exercises must be achieved, prioritizing open specific skill exercises that create optimal pre-match contexts but with specific closed-skill exercises that are key in reducing the inter-variability of the load profile applied to players. Additionally, open-skill tasks may be performed under different structures, prioritizing SSG over rondos in the beginning of the warm-up routine, progressing from simple shooting exercises to tactical combinations and three-player counterattacks in order to increase physiological and biomechanical loading.

Future research should analyze the effects of manipulating the aforementioned variables on short-term performance and readiness compared to the warm-up model of elite futsal teams.

CONCLUSION

The warm-up model routine that emerged from the present investigation pointed out some issues that should be analyzed and discussed under the scope of real-world practices and the state of the art provided by relevant research. The duration of the warm-up was found to be longer than that reported and advised in research that focused on acute performance enhancement following team sports warm-up, which may impact muscle temperature and performance-related variables such as sprint. The sequence of the tasks also raised some questions because physiological load did not have a clear growing intensity and coaches should be aware that activities with high-intensity actions should be placed in the final part of the warm-up routine to ensure the desired acute performance enhancement. Dynamic stretching exercises should be prioritized instead of the static stretching exercises due to the higher transfer effect and should appear in the final phase of the warm-up routine instead of the beginning. The end of the warm-up was dedicated to sprinting tasks, as advised, but the formal variables of these tasks, namely, the limited space they occur, inhibited players to achieve the intended actions, namely, sprinting distance. Apart from these issues, warm-up routines highlighted the value of sport-specific tasks with exercises representative of the most important actions of a futsal match creating ideal pre-match settings adapted by players for the upcoming game. Futsal coaches should be aware of how to manipulate the formal variables of the tasks to allow players to have the correct actions at the correct time under an integrative approach to the physical continuum that should be an elite warm-up routine.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of Universidade da Beira Interior (CE-UBI-Pj-2018-029). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NS, BT, and EA contributed equally to all, including data collection and data analysis. BG contributed to design, data analysis, discussion, tables, and figures. JB contributed to introduction, data analysis, and results. All authors contributed to the article and approved the submitted version.

FUNDING

This work was financed by National Funds through FCT – Portuguese Foundation for Science and Technology under the project UID04045/2020.

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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.

frontiers in Psychology

BRIEF RESEARCH REPORT
published: 14 December 2020
doi: 10.3389/fpsyg.2020.620108

Physiology Responses and Players' Stay on the Court During a Futsal Match: A Case Study With Professional Players

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OPEN ACCESS

Edited by:
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Leonor Gallardo, University of Castilla La Mancha, Spain

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *22 October 2020*
Accepted: *16 November 2020*
Published: *14 December 2020*

Citation:
Dos-Santos JW, da Silva HS, da Silva Junior OT, Barbieri RA, Penafiel ML, da Silva RNB, Milioni F, Vieira LHP, Coledam DHC, Santiago PRP and Papoti M (2020) Physiology Responses and Players' Stay on the Court During a Futsal Match: A Case Study With Professional Players. Front. Psychol. 11:620108. doi: 10.3389/fpsyg.2020.620108

Physiological responses in futsal have not been studied together with temporal information about the players' stay on the court. The aim of this study was to compare heart rate (HR) and blood lactate concentration ([La$^-$]) responses between 1-H and 2-H considering the time of permanency of the players on the court at each substitution in a futsal match. HR was recorded during entire match and [La$^-$] was analyzed after each substitution of seven players. %HR$_{mean}$ (89.61 ± 2.31 vs. 88.03 ± 4.98 %HR$_{max}$) and [La$^-$] mean (8.46 ± 3.01 vs. 8.17 ± 2.91 mmol·L^{-1}) did not differ between 1-H and 2-H (ES, trivial-small). Time in intensity zones of 50–100 %HR$_{max}$ differed only in 60–70 %HR$_{max}$ (ES, moderate). HR coefficient of variation throughout the match was low (7%) and among the four outfield players on the court (quartets, 5%). Substitutions (2 player's participation in each half), time of permanence on the court (7.15 ± 2.39 vs. 9.49 ± 3.80 min), ratio between time in- and out-ratio on the court (In:Outcourt = 1:1.30 ± 1:0.48 vs. 1:1.05 ± 1:0.55 min) also were similar between 1-H and 2-H (ES, moderate and small, respectively). Balancing the number of substitutions, and the In:Outcourt ratio of players in both halves of the match, playing lower time at 1-H, ~8 min for each participation in the match, made it possible to maintain intensity of the match in 2-H similar to the 1H. These results are a good guidance to coaches and for application in future studies.

Keywords: lactate, recovery, team sport, playing time, outfield players, heart rate, intensity of effort

INTRODUCTION

Futsal is an adaptation of soccer for practice on the court played in two halves of 20-min with a 10-min interval between halves, with higher intensity than other team sports as soccer, handball and basketball (Barbero-Alvarez et al., 2008), demanding aerobic and anaerobic pathway. Heart rate has presented 90% of the maximum HR (%HR_{max}) (Barbero-Alvarez et al., 2008) and blood lactate concentration ([La^-]) presented values between 5 and 5.5 mmol·L^{-1} in match (Castagna et al., 2009; Makaje et al., 2012).

The high demand of the match is an indication that the players may have difficulty maintaining the intensity of effort in the second half. Professional futsal players had lower mean HR (HR_{mean}) in the second half (2-H) compared to the first half (1-H), 88.1 vs. 91.1% of HR_{max}, respectively, and percentage of time spent in high intensity HR zone (Barbero-Alvarez et al., 2008). Distance covered in high intensity running also decay in 2-H in official matches (Barbero-Alvarez et al., 2008; de Oliveira Bueno et al., 2014). In contrast, in a simulated match the HR did not differ among the four 10-min periods (Castagna et al., 2009) as well as parameters relationship to the players' sprints did not differ between 1-H and 2-H in official matches of professional players (Barbero-Alvarez et al., 2008; de Oliveira Bueno et al., 2014; Caetano et al., 2015; Vieira et al., 2016), friendly match (Vieira et al., 2016) and simulated match (Milioni et al., 2016).

Reduction of [La^-] after 2-H in universities friendly match (Tessitore et al., 2008) and amateur friendly match (Antunes Neto et al., 2007) has been reported in futsal. However, in simulated match with four 10-min periods the [La^-] remained unchanged, with a mean of 5.3 mmol·L^{-1} (Castagna et al., 2009). Anaerobic metabolism can have an important role to energy provision during the match, however, in studies with team sports the blood samples are collected regularly at the end of half time and it can result in loss of information (Stolen et al., 2005). Since substitutions are unlimited in futsal, to verify players' [La^-] after each substitution during the entire futsal match provides more accurate information for understanding the anaerobic demand. In addition, analyzing the timing of players on the court, as well as the rest time between substitutions, can provide important information for understanding the reduction of physiological responses in 2-H. For example, in soccer it is well established that the HR (Dellal et al., 2012), [La^-] as well as distance covered at high intensity (Stolen et al., 2005) are reduced in the second half. However, substitutes entering the 2-H presented higher HR_{mean} and time > 90% HR_{max} (Coelho et al., 2012) and covered a greater distance at higher intensity (Bradley et al., 2014) compared to the players who started playing. Thus, the aim of this study was to compare HR and [La^-] responses between 1-H and 2-H, considering the time of permanency of the players on the court at each substitution, in a friendly futsal match. Our hypothesis is that if there is a balance in the time the players stay on the court between 1-H and 2-H, the physiology responses can be similar between 1-H and 2-H.

MATERIALS AND METHODS

Participants

Professional futsal players from a team competing in the Paulista League, the main competition of the State of São Paulo, Brazil, were evaluated during a friendly match, in the second week of pre-season. The players trained six times per week, 1.5 h per training session, 11 sessions per week within 6 days (two or one time per day). Of the nine outfield players evaluated, two played only in one half of the match and were excluded from the sample. Thus, seven outfield players composed the sample, two defenders, three wings and two pivots (23.1 ± 2.5 years, 174 ± 6 cm, 76.1 ± 6.6 Kg, 14.0 ± 2.9%) and intermittent aerobic capacity measured by Yo-yo test intermittent recovery level 1 (YYIR-1), 1,497 ± 299 m. The study was approved by the local Ethics Committee of the Scholl of Science of the São Paulo State University (Process 347/49/01/08), according to the laws of the country, and before its beginning, all participants were aware of the objectives and consented to their participation in data collection through a free and informed consent term.

Proceedings

Seven players, from the State League, included in the sample were evaluated during a friendly match against a National League team. The evaluated team played in tactical system 1-3-1 (1-goalkeeper, 2-wingers, 1-defender and 1-pivot), zone marking on the defense half-court most of the match. To encourage the evaluated played, the opponent was one of the best National teams, which had already won National League, South American championships and was composed of three players from Brazil's national team, including the best player of the world at the time. Both teams trained 2 times a week, 1–2 times/day and were in the pre-competition period.

The match was played in an official court (40 × 20 m), lasting 20 × 20 min with a 10 min interval, considering futsal official rules, included the time clocked. No guidance was given to the head coach, and his assistants on substitution procedure, substitutions were made according to the demands of the match and the strategy of the head coach. The match occurred 14 days after the start of the pre-season, physical evaluation 48 h after match, without previous exercise, and anthropometric evaluation 24 h after physical evaluation. HR was recorded during the entire match and blood samples were collected to analyze [La^-] at each player's substitution. In addition, %HR_{max} from four outfield players on the court playing (quartet) was determined at each substitution, considering the %HR_{max} of each quartet.

The ratio between playing and recovering time during the match was verified (In:Out_{court} ratio), considering the time players remained on the court and the subsequent out off the court recovery time, disregarding recovery time between 1-H and 2-H and recovery time after their last substitution. During the out-court period substituted players remained seated or standing, with access to water ad libitum, without ingestion of any nutritional supplement or isotonic drink.

Six authors participated in data collection, one collector for each substituted player, positioned on the side of the substitutes' bench. Four collectors were taking the blood sample for [La⁻] analysis, another collector was monitoring HR and recording player changes in HR software, and the lead author of the study was coordinating and assisting the data collection. The match was filmed with a video camera positioned at the top of the gym, to analyze the substitutions. The characterization of the sample was made with an anthropometric evaluation, including body mass, height, body fat percentage and intermittent aerobic test.

Anthropometric Assessment and Intermittent Aerobic Capacity

All evaluations were performed in the morning, between 9:00 and 10:30 a.m., without previous physical effort, in the week after data collection (2nd evaluation in pre-season). The stature was taken with a stadiometer fixed to the wall and the body mass with portable scale Tanita Ironman BC553 (Tanita Corporation of America Inc., Arlington Heights, IL, United States). Intermittent aerobic capacity was performed YYIR-1, which present reliability and validity (Krustrup et al., 2003). The test consists of covering the distance of 40-m (2 × 20-m shuttle runs) interspersed with a 10-s period of active recovery, with an initial speed of 10 $km \cdot h^{-1}$ and incremental speed to exhaustion controlled by a CD player sound signal to guide the time in which the player must be every 20-m and also the 10 s of recovery between each run of 40-m (Bangsbo, 1994). The percentage of fat was determined by Dual energy Ray-X absorptiometry, Discovery Wi model (Hologic INC, Bedford, MA, United States), with all the procedures of prior analysis and calibration of the equipment made as indicated by the manufacturer.

Heart Rate

HR was recorded by Polar Team System 2 (Polar Electro Oy, Kempele, Fynland) every second during entire match, but the HR considered for analysis was only for the player who remained playing on the court. The HR data was recorded in the Polar Team 2 software, from the same manufacturer, and then transferred and analyzed in the Excel spreadsheet (Microsoft Office, 2010). HR_{max} was considered the highest value between match and YYIR-1 test, the HR_{mean} was expressed in absolute values and relative to $\%HR_{max}$. $\%HR_{max}$ of each quartet was determined at each substitution. The HR was also analyzed in five zones of intensity (50–60, 60–70, 70–80, 80–90, and 90–100% of HR_{max}), considering the percentage of time in each $\%HR_{max}$ zone. Above 90% HR_{max} was considered as the zone of high intensity (Castagna et al., 2009).

Blood Lactate

Samples of blood (25 μl) were taken from the athletes' earlobe, after asepsis with alcohol, and stored in 50 μl of 1% NaF 30–45 s after the player had been substituted and at the end of first and second halves of the match. The samples were frozen and [La⁻] analysis was made in the following week with the YSL 2300 Sports lactate analyzer (YSI, OH, United States), according to manufacturer's directions. [La⁻] mean ($[La^-]_{mean}$) and maximum ($[La^-]_{max}$) were determined considering all player's participation on the court during the match.

Statistical Analysis

Normality of data was tested using the Shapiro-Wilk test. Total time and time of player's participation, HR_{mean}, HR_{max}, $[La^-]_{mean}$, $[La^-]_{max}$, and $In{:}Out_{court}$ ratio of each period which a player remained on the court were analyzed by Student's *t*-test for related samples, after confirming the normality. $\%HR_{max}$ and time in five of $\%HR_{max}$ did not present normal distribution and they were analyzed by nonparametric Wilcoxon signed-rank test. The difference between $\%HR_{max}$ of the four outfield players on the court (quartets) was calculated by Student's *t*-test for unrelated samples. Data were considered from the mean of player's participation in 1-H and 2-H to verify the difference between them, excepting HR and [La⁻] maximum values, which were taken as absolute values for each half. The Coefficient of variation (CV%) of the HR was calculated individually for each player and among the new quartets formed at each substitution, dividing the standard deviation by the mean. Data are reported as mean ± SD with 95% confidence intervals presented. Effect size (ES) was determined by Cohen's *d* effect size for the parametric data (mean difference divided by the square root of the average of the squared standard deviations, SD_{pooled}) and for nonparametric data, Wilcoxon's test, by dividing the Z value by the square root of "n" of the two observations (r-value) (Cohen, 1988; Fritz et al., 2012). Threshold values for Cohen's *d* ES index of the parametric data were considered: trivial < 0.2, small < 0.6, moderate < 1.2, large < 2.0, very large > 4.0, and to nonparametric data, considering r-value between 0.0 and 1.0, ES was considered: trivial < 0.1, small < 0.3, moderate < 0.5, large < 0.7, very large < 0.9, nearly perfect > 0.9, and perfect = 1.0 (Hopkins, 2002; Hopkins et al., 2009). Significance level was set at $p < 0.05$ and data was analyzed by Statistical Package for Social Sciences (SPSS) software, version 20.0 (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp).

RESULTS

HR_{max} was 202 ± 5 bpm (higher value between YYIR-1 and match), representing the mean of 89% of HR_{max}. HR, %HR and [La⁻] were similar in 1-H and 2-H, not differing significantly in both values, mean and maximum (**Table 1**). Match temporal data were also not different between 1-H and 2-H (**Table 1**). CV% mean of the HR of the players throughout the match was 7 ± 2%, 6 ± 1% and 8 ± 2% in 1-H and 2-H, respectively.

Players participated on average twice in each half, one player participated only once in each half, while in 1-H six players participated twice and in 2-H three players participated twice and three players were substituted three times. There were 12 substitutions in each half and the 24 substitutions originated 15 formations from four outfield players on the court

TABLE 1 | Results of the first half (1-H), second half (2-H), and match (1-H and 2-H).

	Match (95% CI)	1-H (95% CI)	2-H (95% CI)	*p*-value	ES (index)
Time of match (min)	67.00	30.28	36.72	-	-
Total time on the court (min)	31.71 ± 9.02 (23.37–40.05)	13.44 ± 5.72 (8.15–18.73)	18.19 ± 6.04 (12.60–23.77)	0.16	0.81 (moderate)
Each participation (min)	8.19 ± 2.27 (6.09–10.28)	7.15 ± 2.39 (4.94–9.35)	9.49 ± 3.80 (5.98–13.01)	0.15	0.74 (moderate)
HR_{mean} (bpm)	179 ± 6 (173–185)	181 ± 5 (176–186)	178 ± 9 (169–186)	0.19	0.43 (small)
HR_{max} (bpm)	200 ± 7 (194–206)	195 ± 9 (187–203)	198 ± 7 (192–204)	0.41	0.38 (small)
$\%HR_{max}$ (%)	88.79 ± 3.35 (85.69–91.88)	89.61 ± 2.31 (87.48–91.75)	88.03 ± 4.98 (83.42–92.63)	0.09	0.45 (small)
$[La^-]_{mean}$ (mmol·L^{-1})	8.32 ± 2.88 (5.65–10.98)	8.46 ± 3.01 (5.67–11.24)	8.17 ± 2.91 (5.48–10.86)	0.62	0.10 (trivial)
$[La^-]_{max}$ (mmol·L^{-1})	9.71 ± 3.00 (6.94–12.49)	9.16 ± 3.16 (6.23–12.08)	9.20 ± 3.14 (6.30–12.10)	0.94	0.01 (trivial)

Values expressed in mean ± SD (95% confidence interval) and difference between 1-H and 2-H. ES, effect size; HR_{mean}, heart rate mean; HR_{max}, maximum heart rate; $\%HR_{max}$, percentage of HR_{max}; $[La^-]$, blood lactate concentration.

(15 quartets, = 88.73 ± 2.49 $\%HR_{max}$), 7 quartets in 1-H (89.57 ± 1.62 $\%HR_{max}$, CI 95% = 88.07–91.07) and 8 in 2-H (88.00 ± 2.98 $\%HR_{max}$, CI 95% = 85.51–90.49), no significant difference between 1-H and 2-H, $p = 0.24$, $d = 0.66$ (ES moderate). There was little variation in HR_{mean} among the four outfields players, quartets, CV% = 5 ± 4% in entire match, 4 ± 3% and 6 ± 4% in 1-H and 2-H, respectively, with only two quartets above 10% (11 and 12%) (**Figure 1**). Percentage time for which the players remained in each of the five $\%HR_{max}$ zone did not differ between 1-H and 2-H either, except 60–70 $\%HR_{max}$ in which players remained longer in 2-H (**Figure 2**): 50–60, $p = 0.07$, $r = 0.49$ (ES, moderate); 60–70, $p = 0.02$, $r = 0.63$ (ES, moderate); 70–80, $p = 0.74$, $r = 0.09$ (ES, trivial); 80–90, $p = 0.74$, $r = 0.09$ (ES, trivial) and 90–100% of HR_{max}, $p = 0.50$, $r = 0.18$ (ES, small). Most of the match the players remained in the zone of higher intensity (> 90% HR_{max}), 55.4 ± 26.3% in entire match, 57.2 ± 26.3% and 54.8 ± 26.3% in 1-H and 2-H, respectively.

$In{:}Out_{court}$ ratio of the players in the entire match presented an average of 1:1.18 ± 1:0.51 min and there was no significant difference between 1-H and 2-H in $In{:}Out_{court}$ (1:1.30 ± 1:0.48 vs. 1:1.05 ± 1:0.55 min, respectively), $p = 0.64$, $d = 0.50$ (ES, small). Total time, and of each player's participation on the court also did not differ between 1-H and 2-H, although these parameters were lower in 1-H (**Table 1**).

DISCUSSION

The aimed of this study was to compare HR and $[La^-]$ responses between 1-H and 2-H, considering the time of permanency of the players on the court at each substitution, including the time of $In{:}Out_{court}$ ratio and HR% from quartets outfield players on the court. Our results confirm our hypothesis that it is possible to maintain similar intensity of effort between the 1-H and 2-H of the match, since HR and $[La^-]$, both mean and maximum, did not differ between 1-H and 2-H (ES, trivial-small), nor did the time players remained in the five HR intensity zones, except to 60–70 $\%HR_{max}$ (ES, moderate).

In a simulated match of 4 × 10 min with 5 min of recovery, the HR_{mean} was not altered throughout the match (Castagna et al., 2009) and between the first and second half (Milioni et al., 2016). In contrast, Barbero-Alvarez et al. (2008) verified lower mean HR in the second half compared to the first half of official matches, 91.1 vs. 88.1% of HR_{max}, respectively. However, players in that study covered the distance of 2,496 and 2,596 m, corresponding to 118 and 111 m·min^{-1} in the first and second half, respectively, approximately 44 min throughout the match, with increase of 12% in the time played in second half. Certainly, players covered a greater distance because they stayed more time on the court, but at lower speed. It is possible that excessive time on the court caused reduction of HR in the second half in that study of Barbero-Alvarez et al. (2008). In matches of the National Leagues of Brazil (Rodrigues et al., 2011) and Spain (Dogramaci et al., 2015), players remained 34 and 39 min on the court, respectively. In the present study, the players remained shorter time on the court (31 min) than players in the above mentioned studies (Barbero-Alvarez et al., 2008; Rodrigues et al., 2011; Dogramaci et al., 2015), and in the present study the players participated in average twice in each half, playing an average of 8 min each on the court. Thus, with a suitable time of 8 min in each participation and total time of 31 min in the match it was possible to maintain the intensity in the 2-H, whereas over 40 min on the court was not possible (Barbero-Alvarez et al., 2008). In addition, another interesting data analyzed in match was to the relationship between the time the players participated in the match and the time they were out of the match, resting ($In{:}Out_{court}$ ratio). There was no difference in $In{:}Out_{court}$ ratio between 1-H and 2-H. This is also another factor that may have contributed to the players maintaining similar effort intensity level between 2-H and 1-H. The literature has not addressed this $In{:}Out_{court}$ ratio which needs to be further studied. $In{:}Out_{court}$ ratio can be a parameter to be studied in future studies as it can have good applicability for coaches.

By stratifying HR in intensity zones it is possible to better analyze the effort intensity. Only in 60–70% of HR_{max} zone players spent more time during 2-H. On the other hand, time spent in three higher $\%HR_{max}$ zone (70–80, 80–90, and 90–100% of HR_{max}) as well as in lower zone (50–60% of HR_{max}) was similar between 1-H and 2-H. Time in lower intensity zones was not very significant for the match, since those two zones are the lowest intensity zones, corresponding to less than 5% of the total match time (see, **Figure 2**), which the players to use to recovery an actions less intensity. In contrast, Barbero-Alvarez et al. (2008) verified a reduction in players' staying time above HR_{max} 85% in the second half of the match

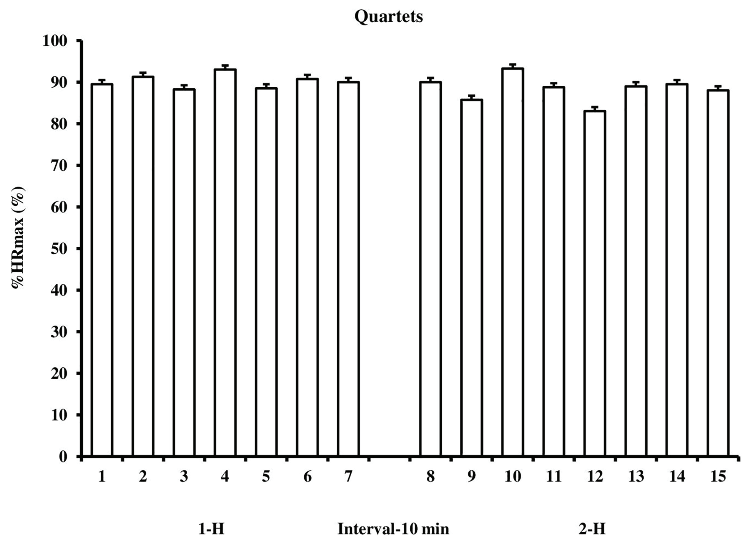

FIGURE 1 | Percentage of maximum heart rate ($\%HR_{max}$), considering mean of quartets (four outfield players on the court) in first (1-H) and second (2-H) halves.

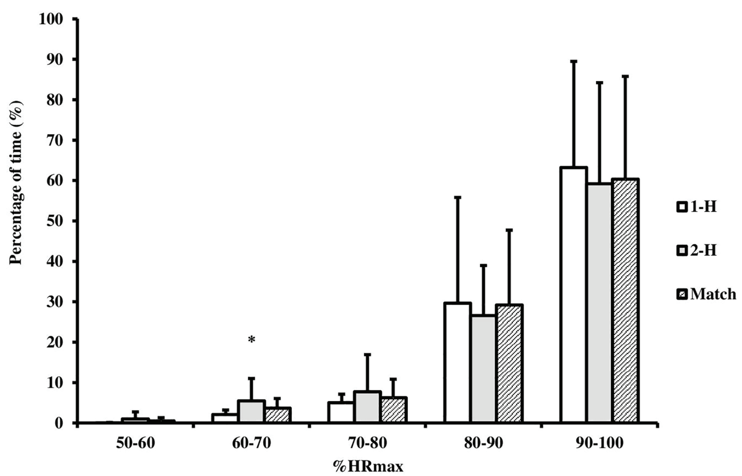

FIGURE 2 | Percentage of time in five zones of $\%HR_{max}$. 1-H = first and 2-H = second halves, match = 1-H and 2-H. *Significant difference between 1-H and 2-H ($p = 0.02$, $d = 0.63$, ES, moderate).

(86 to 79% of the time). As previously mentioned, the time a player remains on the court, certainly, can explain the difference between our results and the study by (Barbero-Alvarez et al., 2008).

In addition to the HR, blood samples were collected throughout the match for [La⁻] analysis at each player's substitution. Although [La⁻] values were high, there was no reduction between 1-H and 2-H. In a simulated match (4×10 min/5 min pause), [La⁻] was not changed during the four periods of the match (Castagna et al., 2009), as well as in a friendly match (Arslanogu et al., 2014). On the other hand, [La⁻] responses were lower in 2-H in friendly matches of universities (Tessitore et al., 2008) and in amateur friendly match in 1-H and 2-H, respectively (Antunes Neto et al., 2007). However, the level of players (amateur) and the absence of substitutions during the match may explain reduction in [La⁻] in 2-H in these two studies. In others team sports, as basketball (Stojanovic et al., 2018) and soccer (Stolen et al., 2005) there is a reduction of [La⁻] between 1-H and 2-H, but with no evidence of [La⁻] reduction at the end of the handball match (Karcher and Buchheit, 2014).

Usually, blood collections in team sports are taken at the end of the first and second half of the match, or only at the end of the match. This can result in substantial loss of information (Stolen et al., 2005). We collected blood at each player's substitution (average 8 min playing on the court), and despite the understanding of the limitation to study the response of

[La^-] in team sports, to our knowledge, this is the first study that has verified [La^-] of all players' participations in futsal match, which ensures a good representation of the [La^-] response in futsal. The highest value of [La^-]$_{mean}$ (8.3 mmol·L^{-1}) verify in a futsal match may be explained by high demand during the match (89% HR_{max} with CV% = 7%), which certainly hampered recovery between intense efforts. In addition, the higher level of the opponent may also have influenced the high demand of the evaluated team, as observed in soccer by Castellano et al. (2011), in relation to displacement in different intensity zones. The low intermittent aerobic fitness (YYIR-1 = 1,497 m) of the players is also a preponderant factor that can explain the high values of [La^-], since the [La^-] response is result of the production/removal ratio, which is influenced by aerobic fitness, among other factors (Stolen et al., 2005). However, despite the low aerobic fitness, playing with a higher quality opponent and the high [La^-] in 1-H, the [La^-] did not reduce in the 2-H.

To our understanding, the HR and [La^-] values similar between the 1-H and 2-H can be explained through the temporal analysis of the players' substitutions and the time on the court. Substitutions were made by the coach, without intervention from the researchers. There were 12 substitutions, players participated two times in each half, with no difference in time on the court between 1-H and 2-H as well as in the $In{:}Out_{court}$ ratio, which certainly influenced the maintenance of the intensity in the 2-H of the match.

In soccer, the intensity of the match is 5–10% lower in the 2-H (Stolen et al., 2005; Dellal et al., 2012), certainly, due to the limited substitutions. Studies on substitutions in soccer have shown that the addition of players in 2-H attenuates the reduction of intensity (Mohr et al., 2003; Coelho et al., 2012; Bradley et al., 2014). In addition, Mohr et al. (2005) demonstrated that fatigue in soccer is temporary, considering intensity reduction after 5 min of intense activities. In futsal, with the possibility of unlimited substitutions, the drop in pace after a period of high intensity can be avoided by replacing one or more players. Reinforcing this idea, in studies on analysis of displacement during the match, de Oliveira Bueno et al. (2014) and Caetano et al. (2015) pointed that the decrease in physical performance or fatigue in futsal can be avoided by increasing the number of substitutions. Our results can also serve as a basis for other sports, such as basketball and handball, due to the similarity in unlimited substitutions, since in basketball HR and [La^-] decay in the second half, and HR in the last quarter is lower than in the other quarters (Stojanovic et al., 2018), and in handball [La^-] and HR responses tend to be similar and slightly lower, respectively (Karcher and Buchheit, 2014). Besides, contextual variables such as location at home or away, tactical system, level of physical fitness, quality of opponent, match status, losing, drawing or winning, among other factors can influence the results and need to be further studied in futsal, since in soccer, it has been shown that contextual variables can influence the performance of the players (Aquino et al., 2017, 2020).

Other interesting data of our study was the $\%HR_{max}$ analysis of the four outfield players who were on the court at each substitution and composed the quartets during the match. $\%HR_{max}$ from quartets did not differ between the 1-H and 2-H. CV% of HR among the four outfield players presented low variations throughout the match 1-H (4%) and 2-H (6%). Result of other studies also indicate that, independent of positions, there is certain uniformity in match demands, to data of repeated sprints (Caetano et al., 2015), muscle damage and inflammation (De Moura et al., 2013). To our knowledge, this is the first study that presents information from the quartet players in futsal, which makes it difficult to compare with the literature. Together, these results indicate that players need the similar level of physical fitness.

This study presents an innovative and useful approach considering the physiological demands related to time on the court, mainly in relation to the response of [La^-], HR of the quartets, and also in the analysis of the intermittent activity of the players' substitutions on the court, such as the $In{:}Out_{court}$ ratio. However, study limitations should be considered, this is a case study, which analyzed only one match, as well as contextual variables were not considered in present study, and can influence the players' performance. On the other hand, considering the high values of [La^-], HR_{mean}, % HR_{max} it is possible assume that players' commitment was similar to that of an official match, since there was a high motivation of the players to confront a national league team with several players from the Brazilian national team, including the best futsal player in the world at that time.

CONCLUSION

The study presents results not yet investigated in the literature, such as the temporal analysis of the substitutions and of [La^-] each substitution of the players. Our results indicate that [La^-]$_{mean}$, $HR_{mean,}$ time of stay in the three highest intensity zones of $\%HR_{max}$ (70–80, 80–90, and 90–100 $\%HR_{max}$) did not alter between 1-H and 2-H. HR_{mean} of the match was similar to previous studies and [La^-]$_{mean}$ was the highest observed in studies of futsal to the moment. $\%HR_{max}$ of outfield quartets presented low coefficient of variation throughout the match well as HR of each player. The temporal analysis of the substitutions collaborated for a better understanding of the changes in the physiological responses between 1-H and 2-H, as well as collecting blood samples at each substitution for [La^-] analysis. Although this is a case study with only one match and this present limitations for generalizing the results, our results are a good guidance to coaches and for application in future studies. Considering that the players did not present a decrease in the HR and [La^-] responses in 2-H and analyzing the match' temporal variables, we suggest that coaches balance the time on the court and the $In{:}Out_{court}$ ratio of players in both halves of the match, with less participation in the first half, an average of 2–3 substitutions for each outfield player in each half of the match, duration of ~8 min for each players' participation, and that the total playing time on the court is not much higher than 30 min.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, requesting the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the School of Science of the São Paulo State University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

The study was designed by JD-S in collaboration with MP and PS who oversaw all procedures and the research phase. All other authors also participated in the discussion and preparation of the drawing. HS, RB, RS, FM, LV, and JD-S performed the data collection, and the data were tabulated and analyzed by OS, MP, DC, and LV. After that, the data were discussed by all the authors together who also collaborated with bibliographic suggestions. After the final editing by JD-S, the text was reviewed by all authors and the suggestions sent, and incorporated into the text for the final version. The final version was sent to everyone for approval before submission to the Journal.

FUNDING

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) and by the Pro-Rectory of Research (PROPE) of the UNESP.

ACKNOWLEDGMENTS

We would like to thank the entire technical committee, the players as well as their managers of the Association Athletic FIB for their support and commitment in carrying out this study.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 18 December 2020
doi: 10.3389/fpsyg.2020.583327

Muscular and Physical Response to an Agility and Repeated Sprint Tests According to the Level of Competition in Futsal Players

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OPEN ACCESS

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *14 July 2020*
Accepted: *30 November 2020*
Published: *18 December 2020*

Citation:
García-Unanue J, Felipe JL, Bishop D, Colino E, Ubago-Guisado E, López-Fernández J, Hernando E, Gallardo L and Sánchez-Sánchez J (2020) Muscular and Physical Response to an Agility and Repeated Sprint Tests According to the Level of Competition in Futsal Players. Front. Psychol. 11:583327. doi: 10.3389/fpsyg.2020.583327

The aim of this study was to evaluate the neuromuscular response to an agility and repeated sprint ability (RSA) test according to the level of competition in futsal players. A total of 33 players from two elite teams and one amateur team participated in the study. The participants completed an agility *t*-test, a 30 m-speed test, and a RSA test. A countermovement jump (CMJ) test and a tensiomyography test of the rectus femoris (RF) and biceps femoris (BF) of both legs were carried out before and after the tests. RSA test revealed better sprint times in elite players compared to amateurs in the seven bouts, as well as in the 30 m sprint and in the agility test ($p < 0.05$). Before the tests, elite players showed higher sustain time (Ts) in RF (+31.03 ms; ES: 0.76) and BF (+28.73 ms; ES: 0.73), higher half-relaxation time (Tr) in BF (+20.79 ms; ES: 0.94), and lower delay time (Td) in BF (−2 ms; ES: 1.19) compared to amateur players. However, post-test values did not present any significant differences ($p > 0.05$). In conclusion, elite players showed greater performance in the RSA test, in the 30 m tests and in the agility test compared to amateur players. The contractile properties were not a key factor in the RSA performance of the futsal players.

Keywords: repeated-sprint ability, tensiomyography, professional sport, sport performance, elite vs. amateur

INTRODUCTION

Futsal is a sport in which players have an average heart rate greater than 85% of their maximum (Rodrigues et al., 2011) and is characterized by a great number of high-intensity efforts such as sprint (actions run over 5.08 m/s), accelerations (actions with a speed increment over 2 m/s^2) or decelerations (break actions run over 2 m/s^2) (Caetano et al., 2015). A recent study using local positioning system revealed that Spanish top futsal players run between 12.30 and 17.54 m per min over 4.19 m/s and between 13.40 and 15.72 m per min with an acceleration over 1.12 m/s^2 (Serrano et al., 2020). Moreover, these players also perform between 7.42 and 9.41 accelerations over 2 m/s^2 per minute, execute between 6.94 and 9.12 decelerations over 2 m/s^2 per minute or run between 0.58 and 0.88 sprints per minute; what might explain why VO_{2max} levels in futsal players can exceed 60 ml/kg/min (Castagna et al., 2009; Rodríguez-Ruiz et al., 2012).

These findings, as well as those from previous studies (Castagna et al., 2009; Castagna and Alvarez, 2010), show that players' ability to maintain high-intensity actions in futsal matches is a key element of performance. In fact, futsal seems to demand a greater amount of high-intensity actions than other team sports like basketball, handball, or soccer (Naser et al., 2017). Thus, it can be expected high-intensity actions like sprints to be affected by a decrement in torque production of the knee flexor and the extensor muscles of futsal players due to acute fatigue (Dal Pupo et al., 2017). The unlimited changes allowed in futsal matches seems to counteract the effect of fatigue as variables like distance covered per minute, peak velocity, initial velocity, recovery time between sprints, sprints performed per minute, explosive distance per minute or number of accelerations, and decelerations per minute do not decrease in the second half of the game (Caetano et al., 2015; Serrano et al., 2020). However, the repeated sprints actions separated by a short period of rest (15, 30, 45, or 60 s) are frequent in futsal (Caetano et al., 2015), so players' neuromuscular response and resistance to fatigue play a fundamental role in decisive actions of the game despite the unlimited changes (Loturco et al., 2015).

Repeated Sprint Ability (RSA) tests are considered as one of the main instrument to analyze the ability of futsal athletes to deal with repeated high-intense actions (Barbero-Alvarez et al., 2008; Sánchez-Sánchez et al., 2018). This test has proved to be useful to analyze the effect of resting between seasons in futsal players (Njororai, 2007) and to discriminate between playing level as those with lower performance decrease in the RSA test showed a higher number of high intensity actions during a real game situation (Carling et al., 2012). Existing evidence suggests that factors like explosive strength, muscle stiffness or intersegmental coordination of lower limbs might play a key role in the ability of athletes to cope with repeated sprints (Stojanovic et al., 2012; Dal Pupo et al., 2017) what might be affected by acute fatigue (Milioni et al., 2016). However, a recent study found that acute fatigue deteriorates neither muscle stiffness nor the intersegmental coordination of futsal players' lower limbs despite it does damage some kinematics of lower limbs (Dal Pupo et al., 2017). Therefore, further research is needed to understand how futsal players' lower limbs cope with the demands of repeated sprints.

The study of the neuromuscular responses of futsal players' lower limbs to induced fatigue might be useful for this regard. The tensiomyography, a non-invasive technique that evaluates the muscle response to electrical stimuli (Sánchez-Sánchez et al., 2018) is useful to measure neuromuscular responses as it provides information on the rigidity of the muscle, contraction velocity, and state of fatigue (Miller et al., 2006; Rodrigues et al., 2011). The easiness of using this tool compared to others like electromyography or biomarkers combined with high levels of reproducibility and reliability for measuring vastus medialis, vastus lateralis, rectus femoris (RF), and biceps femoris (BF) (Warren et al., 2001; Spencer et al., 2005; Carrasco et al., 2011; Rodrigues et al., 2011), makes it a reliable method for comparing muscle response in different players (Sánchez-Sánchez et al., 2014; Wiewelhove et al., 2015).

Sánchez-Sánchez et al. (2018) reported that acute fatigue induced by a RSA test causes alterations in the contractile properties of the RF and BF of top futsal players. But it remains unknown if the alteration of lower limbs' neuromuscular responses due to acute fatigue differ according to factors like the playing level or how contractile properties of lower limbs are related to the performance in RSA. For this reason, the aim of the present research was to evaluate the neuromuscular response to an agility and RSA test according to the level of competition in futsal players. It was hypothesized that elite players would obtain better results in the RSA test, as well as a lower decrease in performance during the test. Regarding the neuromuscular responses, it was hypothesized a significant relation of these responses with the RSA test results.

MATERIALS AND METHODS

Participants

The sample was composed of three teams of the Spanish National Futsal League (LNFS), two elite teams and one amateur team. A total of 33 players were analyzed (stature: 175.48 ± 5.73 cm; body mass: 73.43 ± 5.93 kg; fat mass: 13.25 ± 3.57%). A stratified random sampling test was carried out according to the level of the teams (elite, $n = 20$; amateur, $n = 13$). Contact with the clubs was carried out through the LNFS. The ages of the participants ranged from 18 to 28 years (23.4 ± 4.42 years). Prior to participation in the study, all participants signed an informed consent form, which explained the test procedures and possible risks. The study protocol was approved by the Local Ethics Committee and was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Experimental Design

The data collection process took place from September to December of 2019 after 1 month of pre-season training, and each team arranged with the researchers 3 days within this period to allow the players to perform the proposed test. The doctors of each team excluded all players who were in no condition to perform eccentric high-intensity exercises or had had an injury within the last 6 months. Previous to this study, players performed an initial pilot test to become familiar with the tests included in the study protocol. Participants agreed not to perform any exhausting activity 24-h before testing. Moreover, the head coach did not arrange any training drill 24-h before the testing. The tests were carried out on the futsal field.

Experimental Protocol

Firstly, fat mass (g and %) and lean mass (g) of both legs were measured using bioelectrical impedance (Tanita BC418-MA, Tanita Corp., Tokyo, Japan). The SECA scale (model 711; SECA GmbH & Co., KG, Hamburg, Germany) was used to measure the height of the participants. Participants agreed to not to eat 3 h prior to the test, refrained from taking alcohol, or stimulant beverages for at least 15 h prior the test, drunk around 30 mL of water 90 min prior to the study in order to be hydrated when conducting the test and urinated a few minutes before the test (Poliszczuk et al., 2013; López-Fernández et al., 2020). Finally, composition for all subjects was estimated using the standard prediction equations rather than those designated for athletes.

Warm-Up Procedure

Participants performed a standard warm-up composed of 5 min of continuous running, 5 min of exercises of articulation mobility, and two 30-m sprints separated by 2 min of recovery. Stretching exercises were not part of the warm-up.

Baseline Assessments

Countermovement jumps (CMJ) were assessed using an infrared system (Optojump Next, Microgate, Bolzano, Italy). Participants placed both hands on their hips to avoid the influence of the movement of the arms on jump performance. Each player performed two jumps with 2 min recovery between jumps. The best of them was selected for statistical analysis.

Also, the muscular responses and the lateral symmetry of both the RF and BF were assessed by means of tensiomyography (TMG-100 System electrostimulator, TMG-BMC d.o.o., Ljubljana, Slovenia). This assessment provided the following information: the maximum radial displacement of the muscle belly (Dm), Contraction time (Tc), Delay time (Td), sustained contraction time (ts), and half-relaxation time (tr) of these muscles under basal conditions. Four stimuli of varying the amplitude (25, 50, 75 and 100 mAp) were given to both muscles for 1 ms. The rectus femoral was measured with the subject in a supine position, and with the knee maintained in a position of 120° flexion with the help of a foam triangular cushion. The biceps femoral was measured with the subject in the prone position, and with the knee maintained in a position of 5° flexion with the help of a foam cushion.

Dm (mm) is a parameter which reflects the maximum radial displacement of the muscle belly as a consequence of the muscle contraction and depends on the flexibility and the tone of the muscular tissue. Therefore, Dm values increase when the explosive force is developed, involving high movement amplitude, and they decrease under the conditions of a high muscular tone. Td (ms) is the time lapse between the transmission of the electric stimulus and the onset of muscle contraction (10% Dm). Tc (ms) is the time between the moment when the muscular contraction is 10% of the Dm and the moment when the contraction reaches 90% of the Dm. Ts (ms) is the time lapse when the muscle contraction remains above the 50% of the Dm. Finally, Tr (ms) is the time between the moment when the muscular contraction is 90% of the Dm and the moment when the contraction falls below 50% of the Dm. The electric stimulus is measured placing perpendicular to the muscle belly a digital Dc-Dc transducer Trans-Tek® (GK 40, Panoptik d.o.o., Ljubliana, Slovenia), through two self-adhesive electrodes (TMG electrodes, TMG-BMC d.o.o. Ljubljana, Slovenia) placed equidistant at a distance of 50–60 mm from the digital transducer. Both positions of the sensor and the electrodes were marked with a permanent marker to ensure that all subsequent measurements were performed at the same point. All measurements were carried out by the same expert technician.

Performance Tests: The Agility *T*-Test and the 30-m Speed Test (RSA Test)

The Agility *t*-test was used to determine the performance in an action with changes of direction (Murayama et al., 2000). A pair of photocells (Witty, Microgate, Bolzano, Italy) was placed at the start line to measure total time.

Additionally, maximum speed was assessed using a 30-m speed test at the end of the warm-up. Total time was evaluated with two pairs of photocells located at 0 and 30 m. The RSA test included seven 30-m sprints with 20 s of recovery between sprints. Two pairs of photocells (Witty, Microgate, Bolzano, Italy) placed at 0 and 30 m were used. This test was performed according to the methodology proposed in previous studies (Barbero-Alvarez et al., 2008). The best sprint time (RSA_{BEST}), the mean time (RSA_{MEAN}), the total time (RSA_{TT}), the percent sprint decrement {RSA_{DEC} = [(total sprint time – best time*7)/best time*7]*100}, and the percent difference from best and worst sprint during the RSA test {RSA_{CHANGE} = [(worst time – best time)/best time]*100} were also calculated (Chaouachi et al., 2010). The two previous sprints performed during the warm-up were used as control measure to guarantee players did the RSA test at maximum speed. If the time of the first sprint of the RSA test was higher (> 5%) than the best individual sprint performed prior to the beginning of the test, the RSA test was not considered valid and the player had to repeat the test after 5 min of recovery.

Post-performance Tests Assessment

Countermovement jumps (CMJ) and the tensiomyography were assesed again after the Agility *t*-test and the RSA test following the same protocol.

Statistical Analysis

Data are presented as mean ± standard deviation. Statistical analyses were performed using SPSS (SPSS, version 21.0 for Windows, IBM Corp., New York, NY, United States). Normal distribution and homogeneity of variance was confirmed by Shapiro–Wilk test and Levene test, respectively. Differences in performance on the RSA test, the agility test, and the 30-m test between elite and amateur players were analyzed using a *t*-test for independent samples. Two-ways of variance (ANOVA) was used to analyze the differences in the tensiomyography and CMJ variables as a function of the moment (pre-post) and competitive level (elite-amateur). Bonferroni *post hoc* tests were used for the pairwise comparisons. In addition, confidence interval (CI of 95%) and the effect size (ES; Cohen's d) were calculated to identify the magnitude of changes between groups. The ES was evaluated following the next criteria: 0–0.2 = trivial, 0.2–0.5 = small, 0.5–0.8 = moderate, and >0.8 significant (Cohen, 1992). Finally, the relationship between RSA scores and delta scores (post-pre in percentage) of tensiomyography variables was evaluated by linear regression analysis. One model was estimated for each tensiomyography variable, using the same independent variables in all of them (RSA_{TT}, RSA_{DEC}, and RSA_{CHANGE}). The competitive level was included as categorical covariate (elite players were used as the reference group). The model did not present problems of heteroscedasticity. Moreover, variance

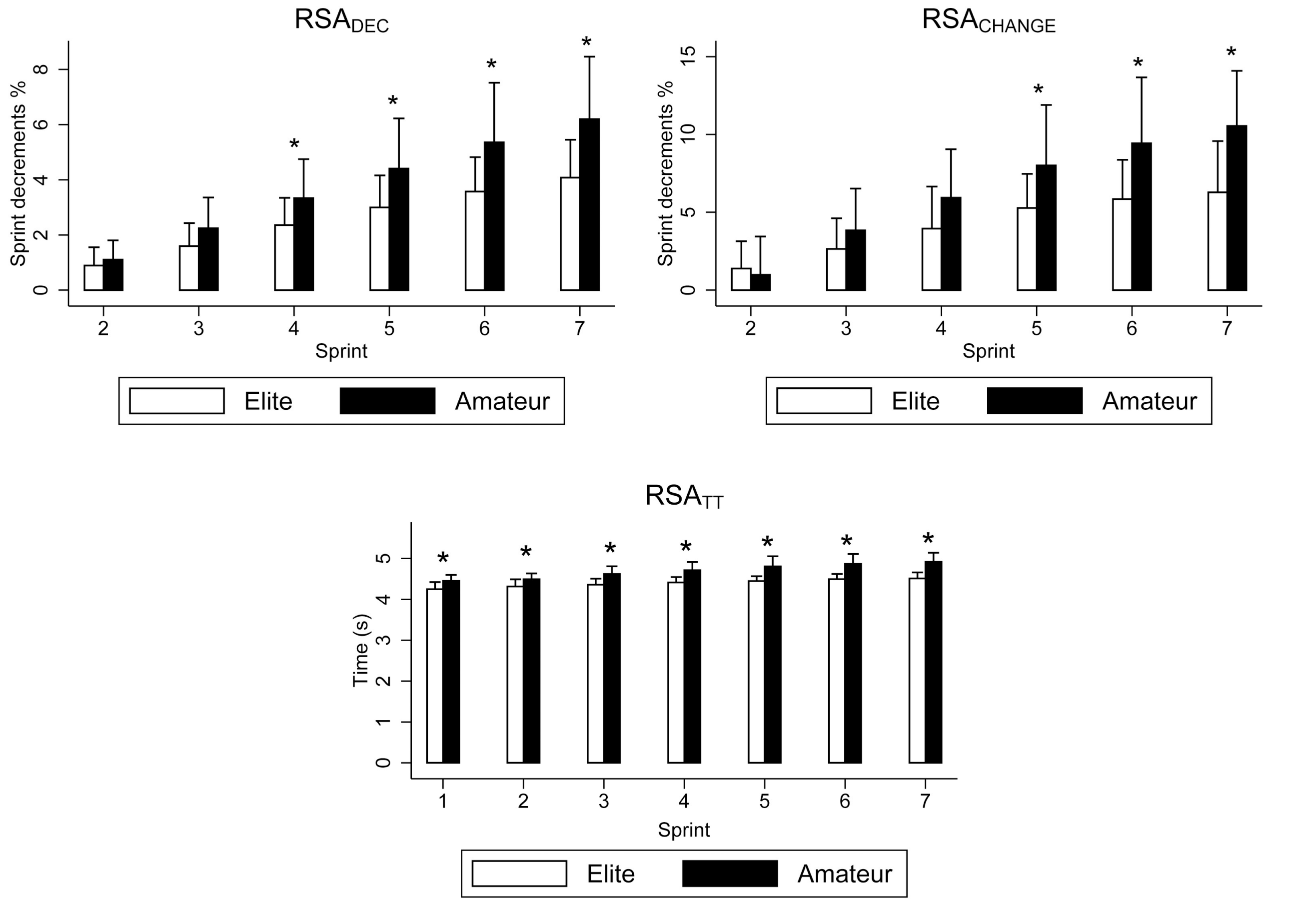

FIGURE 1 | Differences in the results of the RSA test between elite (*n* = 20) and amateur (*n* = 13) futsal players. *$p < 0.05$.

inflation factor (VIF) was calculated to adjust the regression and prevent multicollinearity problems. The level of significance was established at $p < 0.05$.

RESULTS

The outcomes from the RSA test are displayed in **Figure 1**. Elite players showed lower RSA$_{TT}$ (−2.95 s; ES: 1.59; CI 95%: −4.46 to −1.45; $p < 0.001$), RSA$_{BEST}$ (−0.19 s; ES: 1.27; CI 95%: −0.30 to −0.08; $p < 0.001$) and RSA$_{MEAN}$ (−0.30 s; ES: 1.89; CI 95%: −0.41 to −0.19; $p < 0.001$). Furthermore, they achieved better sprint times than amateur players from the first repetition (−0.06 s to −0.41 s; ES: 1.10–2.20; $p < 0.01$). On the other hand, amateur players showed higher RSA$_{DEC}$ from the fourth sprint ahead (+0.97% to +2.12%; ES: 0.37–1.05; $p < 0.05$), and higher RSA$_{CHANGE}$ from the fifth sprint ahead (+2.73 to +4.27; ES: 0.90–1.25; $p < 0.05$). Regarding the performance evaluation, the results showed better times in the 30 m sprint (−0.17 s; ES: 0.86; CI 95%: −0.31 to −0.03; $p = 0.01$) and agility test (−0.62 s; ES: 2.30; CI 95%: −0.81 to −0.42; $p < 0.001$) in elite players.

Table 1 shows the tensiomyography results before and after the RSA test according to the level of the players. The variance analysis revealed a significant reduction in the Td (−1.22 ms; ES: 0.87; CI 95%: 0.003–2.436; $p = 0.049$), Ts (−49.16 ms; ES: 1.21; CI 95%: 26.19–72.14; $p < 0.001$), and Tr (−9.85 ms; ES: 0.90; CI 95%: 10.97–48.73; $p = 0.002$) in the RF, and the Ts (−56.23 ms; ES: 1.31; CI 95%: 33.01–79.44; $p < 0.001$) in the BF, of elite players. On the other hand, amateur players showed a significant reduction of the Td (−1.71 ms; ES: 0.71; CI 95%: 0.20–3.22; $p = 0.027$) in the RF, and the Ts (−38.35 ms; ES: 2.10; CI 95%: 9.55–67.14; $p = 0.010$) in the BF after the RSA test. When comparing between groups, the basal test revealed elite players to have higher Ts in RF (+31.03 ms; ES: 0.76; CI 95%: 5.15–56.92; $p = 0.020$) and BF (+28.73 ms; ES: 0.73; CI 95%: 2.58–54.88; $p = 0.032$) and Tr (+20.79 ms; ES: 0.94; CI 95%: 1.60–39.98; $p = 0.034$) in BF. In addition, higher Td (+2.00 ms; ES: 1.19; CI 95%: 0.82–3.18; $p = 0.001$) in BF were found in amateur players in pre values. These differences disappeared after the RSA test ($p > 0.05$).

The linear regression analysis comparing the relationship between RSA scores and delta scores (post-pre in percentage) of tensiomyography is displayed in **Table 2**. The RSA$_{TT}$ and RSA$_{DEC}$ showed a positive relation with Td of the RF ($p < 0.05$). Furthermore, RSA$_{TT}$ evidenced a negative relation with the Ts of the BF ($p < 0.05$). However, the adjusted R2 is very low so it is the level of confidence.

TABLE 1 | Two-way ANOVA differences pre-post and elite-amateur.

		Elite (n = 20)		Amateur (n = 13)	
		PRE	POST	PRE	POST
RF	Td (ms)	23.68 ± 1.71	22.47 ± 1.06*	24.62 ± 3.14	22.91 ± 1.69*
	Tc (ms)	29.65 ± 6.38	26.80 ± 3.25	31.19 ± 6.48	28.60 ± 4.79
	Ts (ms)	122.90 ± 49.62#	73.73 ± 31.41*	91.87 ± 31.72	65.24 ± 18.94
	Tr (ms)	63.91 ± 37.48	34.07 ± 29.06*	46.92 ± 27.15	27.86 ± 17.61
	Dm (mm)	7.15 ± 2.53	8.08 ± 1.79	6.76 ± 2.06	7.32 ± 1.95
BF	Td (ms)	22.78 ± 1.09#	22.47 ± 1.26	24.78 ± 2.26	23.57 ± 2.16
	Tc (ms)	28.47 ± 7.92	29.03 ± 10.13	33.61 ± 7.75	32.23 ± 7.94
	Ts (ms)	209.34 ± 53.87#	153.11 ± 32.08*	180.61 ± 24.42	142.26 ± 12.18*
	Tr (ms)	62.70 ± 33.48#	48.97 ± 30.90	41.90 ± 10.73	45.30 ± 18.70
	Dm (mm)	5.70 ± 2.16	5.48 ± 2.03	5.95 ± 2.11	5.21 ± 1.72
CMJ (cm)		35.73 ± 5.97	34.00 ± 4.27	33.82 ± 4.20	31.77 ± 3.60

**Differences for pre-post for $p < 0.05$. #Differences between elite and amateur futsal players. RF, rectus femoris; BF, biceps femoris; Td, delay time; Tc, contraction time; Ts, sustain contraction time; Tr, half-relaxation time; Dm, maximum radial displacement of muscle; CMJ, countermovement jump.*

TABLE 2 | Regression analysis comparing the neuromuscular parameters and the outcomes from the repeated sprint ability (RSA) test standardized coefficients.

	Td (%)	Tc (%)	Ts (%)	Tr (%)	Dm (%)
RF					
Level	−1.12	−10.73	1.95	8.67	−21.82
RSA_{TT}(s)	0.09	2.93*	−0.95	−5.35	−6.34
RSA_{DEC}%	2.80	8.26*	5.03	6.65	6.46
RSA_{CHANGE}%	−1.48	−3.59	0.08	1.53	0.50
Constant	−6.56	−89.78*	−28.62	76.67	216.04
Adjusted R2	0.10	0.35	0.17	0.14	0.08
BF					
Level	−1.82	−3.83	6.64	27.43	−7.04
RSA_{TT}(s)	0.20	1.31	−2.03*	−1.88	−2.32
RSA_{DEC}%	0.71	−0.50	4.25	10.11	−8.25
RSA_{CHANGE}%	−0.90	−1.69	−1.09	−4.89	5.65
Constant	−1.53	−16.21	19.61	11.72	66.80
Adjusted R2	0.24	0.08	0.32	0.11	0.15

**$p < 0.05$. RF, rectus femoris; BF, biceps femoris; Td, delay time; Tc, contraction time; Ts, sustain contraction time; Tr, half-relaxation time; Dm, maximum radial displacement of muscle; Level: elite players were used as reference group.*

DISCUSSION

The results of the present study show that elite futsal players have a higher performance in RSA test. Some differences in contractile properties of BF between elite and amateur players were found in the basal test. However, the regression analysis showed no clear relationship between RSA performance and tensiomyography variables as the few found associations displayed a low level of confidence.

The elite players obtained better results in the average time (RSA_{MEAN}), total time (RSA_{TT}), and best time sprint (RSA_{BEST}) variables. In relation to performance deterioration, amateur players showed a greater effect of fatigue from the fourth sprint onward. This might be due to amateur players have lower levels of VO_{2max} and muscle glycogen concentration than elite layers (Balsom et al., 1999; Bishop and Spencer, 2004; Makaje et al., 2012).

Previous investigations reported that Dm and Tc are the contractile properties that possess greater precision and sensibility when assessing the effects of training (Doğramaci et al., 2015; Wiewelhove et al., 2015). These studies coincide in that muscle fatigue is mainly characterized by increasing Dm and decreasing Tc. This relation would be caused by a loss in the efficiency in the excitation-contraction coupling, deterioration in membrane conduction properties, and a destruction of cellular properties (Doğramaci et al., 2015). This mechanism would cause a greater structural tension in the cell during resting state and an inability to completely active the contractile processes (Murayama et al., 2000; Byrne et al., 2004; Tous-Fajardo et al., 2010). Our result showed a slight increase of Dm and decrease of Tc in RF after completing the RSA test. However, the lack of significant differences between basal and post measures suggest that the RSA test conducted in this study did not produce a significant effect on the contractile properties of the studied muscles.

Regarding the Ts, our results show a general significant decrease after the RSA test in both amateur and elite players, existing also differences according to the level of competition of the players. In this sense, elite players showed a greater ability for maintaining muscle contraction (higher Ts) at basal state compared to amateur players in both the RF and the BF. Although these differences disappeared after completing the RSA, the Ts parameter of the BF might be susceptible of identifying differences in the players performance according to their competitive level. However, further studies are required due to the regression analysis did not show a strong relationship between the RSA outcomes and Ts of BF.

Shorter vales in Td has been suggested to indicate a higher ability to generate rapidly force in actions demanding repeated muscle contractions (Rey et al., 2012). This study is somehow in line with these assumptions as elite players displayed lower Td than amateur ones with significant differences for BF. However, the regression analysis does not support a the hypothesis of a previous study that suggested that higher Td might indicate a lower ability for repeated high-intention actions as those demanded by RSA test (Sánchez-Sánchez et al., 2018).

The sample of the present study was composed by amateur and elite players with similar basal contractile properties in the RF (no significant differences were found except in the Ts) but clearly different in the BF (Td, Ts, and Tr differ significantly). Therefore, it is logical to think that the differences in sprint performance observed in the present study between elite and amateur players could be partially caused by differences in the conditioning of the hamstring muscles, as these are the main muscles involved in controlling running activities and stabilizing the knee during turns and other actions (García-Manso et al., 2011). Moreover, in maximum sprint actions like those developed in this study, the hamstring muscles play a fundamental role in knee flexion as when running a maximum intensity, the heel elevation during the recovery phase is a rapid and explosive action (Girard et al., 2011). However, the regression analysis revealed none of the studied variables to have a strong association with the RSA performance what indicates that contractile properties of RF and BF cannot be used to this purpose.

To conclude, it is important to acknowledge the limited sample size of this study despite a stratified random sampling test was carried out according to the level of the teams. Additionally, the authors acknowledge that factors like the possible co-activation of neighboring muscles might affect the outcomes from the tensiomyography test (Martín-Rodríguez et al., 2017). However, to overcome this limitation the tests were conducted by the same technician who had a high experience using the tensiomyography.

PRACTICAL APPLICATIONS

In light of the results, we can conclude that elite players show greater performance in the RSA test, in the 30 m tests and in the agility test compared to amateur players. Also, elite players showed less performance decrement than amateur players from the fourth sprint onward in the RSA test. Regarding the neuromuscular profile between both populations, elite players showed differences in the contractile properties of BF in basal test. However, the regression analysis suggest that these differences do not play a key role in a RSA test in futsal players.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by European University of Madrid. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JG-U, JS-S, and JL-F carried out the data acquisition process and drafted the manuscript. LG provided access to the measurement equipment and contributed to the design and work planning of the data acquisition process. JG-U, DB, JF, and EC performed the data analysis and interpretation of the results. JS-S, EH, and JL-F provided advice and critically reviewed the manuscript. LG and DB coordinated all parts, contributed to the data acquisition process and critically reviewed the manuscript. All authors have read and approved the content of the manuscript, contributed significantly to the research of the present manuscript, and approved the final submitted version of the manuscript.

FUNDING

JG-U acknowledges that his participation in this study was financed by "Fondo Europeo de Desarrollo Regional, Programa Operativo de la Región de Castilla-La Mancha" (2018/11744).

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 07 January 2021
doi: 10.3389/fpsyg.2020.623480

The Goal Scale: A New Instrument to Measure the Perceived Exertion in Soccer (Indoor, Field, and Beach) Players

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Edited by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *30 October 2020*
Accepted: *07 December 2020*
Published: *07 January 2021*

Citation:
Polito LFT, Marquezi ML, Marin DP, Villas Boas Junior M and Brandão MRF (2021) The Goal Scale: A New Instrument to Measure the Perceived Exertion in Soccer (Indoor, Field, and Beach) Players. Front. Psychol. 11:623480. doi: 10.3389/fpsyg.2020.623480

The rating of perceived exertion (RPE) can be used to monitor the exercise intensity during laboratory and specific tests, training sessions, and to estimate the internal training load of the athletes. The aim of the present study was to develop and validate a specific pictorial perceived exertion scale for soccer players (indoor, field, and beach soccer) called GOAL Scale. The pictorial GOAL Scale (six drawings; 1 “low exertion” to 6 “exhaustion”) was validated for twenty under-17 soccer players (16.4 ± 0.68 years; 175.4 ± 9 cm; 66.4 ± 7.7 kg; % fat mass 12.4 ± 3.3). In the validation phase, the athletes were evaluated in a progressive protocol involving stimuluses of 3 min with 1 min for the rest into the stages until the voluntary exhaustion in Maximal Cardiopulmonary Effort Test (MCET), and in the Yo Yo Intermittent Recovery Test – Level 1 (Yo-Yo). The RPE identified by the GOL Scale, by the Borg Scale 6 – 20 and by the Cavasini Scale, as well as the heart rate (HR), perceptual of the heart rate (%HR_{max}) and the blood lactate concentration ([La]) were immediately evaluated after each stage of both tests. Spearman’s correlation coefficient ($p < 0.05$) was used. Construct scale validity was examined by regressing GOAL Scale against Borg Scale 6 – 20 and Cavasini Scale and concurrent scale validity was investigated by regressing GOAL Scale against HR, beats/min and blood lactate concentration (mmol/L) during two progressive tests. There was a significant correlation values of the GOAL Scale with Borg Scale ($r = 0.93$; $r = 0.88$), Cavasini Scale ($r = 0.91$; $r = 0.90$), %HR_{max} ($r = 0.91$; $r = 0,86$), HR ($r = 0.87$; $r = 0.83$) and lactate ($r = 0.68$; $r = 0.83$) during tests (Maximal Incremental Cardiopulmonary Test and Yo-Yo test, respectively). The results evidenced concurrent and construct validity of the GOAL Scale across a wide range of exercise intensity. The absence of verbal anchors makes the use of this instrument to soccer, futsal and beach soccer athletes of different languages and different literacy levels possible.

Keywords: psychophysiology, athletic performance, effort, fatigue, differentiated RPE

INTRODUCTION

In general, the sports performance has been studied for researchers of different areas, once the systematic planning of athlete training programs is supposed to integrate physiological, biomechanical, nutritional, psychological and social dimensions (Mujika et al., 2018).

From the physical perspective, the increase of athlete's performance of different sports, including futsal, beach soccer, and field soccer athletes shows a straight relationship with the proper control of the training units, including volume, intensity, and density of training (relation between total volume and session time) (Veugelers et al., 2016; Ribeiro et al., 2020). It is possible to affirm that this control is a great challenge for the physical trainers, once the low stimulus is not enough to generate positive adaptations of performance, while the excessive and rapid increases in training loads can contribute to the increase of the impairments (Gabbett, 2016).

Thus, the measure of the parameters which indicate the intensity of effort in which the athletes are submitted during the routine of training is necessary. These parameters can be analyzed by the physiological variables such as the oxygen consumption (VO_2), the heart rate (HR), the ventilator anaerobic thresholds, blood lactate concentration (Bellotti et al., 2013), and by psychophysiological variables such as the ratings of perceived exertion (RPE) (Borg, 1962), the total quality recovery (McGuigan, 2017), Hooper index (Hooper and Mackinnon, 1995), and the questionnaire of training load evaluation in soccer (Rebelo et al., 2012).

According to Borg (1962); Noble and Robertson (1996), and Borg and Kaijser (2006), the RPE is a variable frequently used in physical exercise ambit and, more specifically, in sports because it has a great correlation with other exertion and objective parameters, such as heart rate and blood lactate. According to Impellizzeri et al. (2005) the RPE is a variable frequently used in the soccer as well, as it makes it possible for coaches and physical trainers to evaluate the intensity of the exercises exerted in a training session.

Recently, Thorpe et al. (2016) highlighted the importance to the use of psychometric instruments in training routine (scales and questionnaires), and they were able to show that the recovery was better identified by the Total Quality Recovery (TQR) scale rather than by the heart rate variability, a gold standard parameter used to evaluate recovery in sports. The former is a subjective method while the latter is an objective one but it requires more complexity as more costly instruments are involved, limiting its application in clubs from different economic backgrounds.

Based on this reality, the literature reveals that both the Borg RPE scale Borg (1962, 1998) and the Borg CR10 Scale adapted by Foster et al. (2001) are the most frequently used instruments for the effort measurement and training load in soccer and futsal athletes (Moreira et al., 2013; Polito et al., 2017). It is important to highlight here that the Foster's Scale was not validated using the psychophysical principles, which can be observed by the use of the "Maximal" anchor at number 10, which introduces a ceiling effect that roots out the scale properties.

However, it is important to highlight that the RPE instruments cited were created and validated to be used for all kind of sports and even several kinds of perceptions, and symptoms. So, these instruments do not take in account the specificity of the athletes, including soccer players. Besides that, a very common problem is that the translations of the original instrument have been done without proper cross-cultural adaptation processes, which contributes with the same instrument using different verbal anchors for the same level of the scale. Other limitation of the verbal scales is that not all individuals are able to interpret verbal anchorages adequately, which may be related to the level of literacy of the evaluated subjects.

Following this train of thought, Bar-Or and Ward (1989), Robertson et al. (2000); Kang et al. (2003), Utter et al. (2006), and Chen et al. (2017), argued that scales consisting solely of pictorial images are easier to understand to apply in different groups, which may minimize the limitations in the interpretation of psychophysiological perception and its evaluation. In addition to this, the ecological validity is increased when instruments and assessments comprehend biocultural manifestations of the specific context of the sport (Tenenbaum and Bar-Eli, 1995; Yelling et al., 2002; McGuigan, 2017).

The initial hypothesis was which the GOAL scale has high correlation levels with the physiological and psychophysical indicators, being then an alternative to identify the perceived exertion in soccer athletes without the risk of semantic problems found in the verbal scales. Therefore, the objectives of the present research were: (1) to elaborate a specific pictorial scale of the perceived exertion for soccer athletes called GOAL Scale; (2) to explore the association between the GOAL Scale and physiological indicators (heart rate – HR, percentage of maximal heart rate – % HRmax, oxygen consumption – VO_2, percentage of maximum oxygen consumption – VO_{2max}, blood lactate concentration); (3) to explore the association between the GOAL Scale and the other constructs already validated for the RPE measurement (Borg RPE 6–20 and Cavasini Scale). Cavasini Scale was validated for Brazilian people, consisting of 11 numeric anchorages and just 2 verbal anchorages (Cavasini and Matsudo, 1993).

MATERIALS AND METHODS

General Design

The present experimental research occurred in four steps as follow: (1) initial creation of GOAL Scale by a professional cartoonist; (2) validation by judges; (3) laboratorial validation; (4) field test validation (**Figure 1**).

The GOAL Scale was originally developed by a professional cartoonist. Initially, it was constituted of six images and their respective numbers (1 to 6), without any verbal anchorage. The initial requirements for the drawing of the cartoons referred to the appearance resulting from the physiological adjustments caused by the increase of effort load during the practice of the activity, including changes in the rate of sweating, facial flushing, and hyperventilation. The initial criteria established by the authors considered two images for each exercise phase,

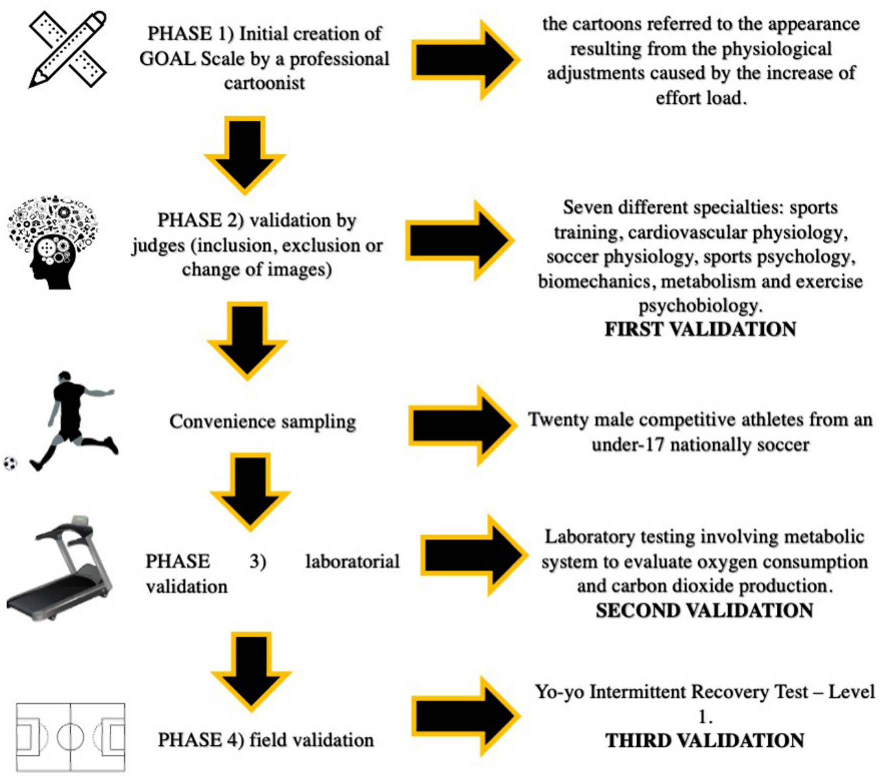

FIGURE 1 | Schematic figure of the experimental design.

according to the multiple threshold model proposed by Skinner and McLellan (1980). In the second phase, the instrument was sent to nine Ph.D. professors, from seven different specialties for evaluation and positioning: sports training, cardiovascular physiology, soccer physiology, sports psychology, biomechanics, metabolism, and exercise psychobiology. After receiving the initial instrument, each judge had a period of 3 months to suggest the inclusion' of new images, the exclusion of one or more of the six initially elaborated or the change of any details in any existing image of the instrument.

Thereafter, the GOAL Scale was tested in two different cardiorespiratory maximal tests: laboratory testing involving metabolic system to evaluate oxygen consumption and carbon dioxide production, and a field test which was validates to be applied in soccer players, the Yo-yo Intermittent Recovery Test – Level 1 (Castagna et al., 2006). The interval between the two tests was 1 week.

In order to have a better control of the test, the following measures were adopted: (1) familiarization of researchers and athletes in both tests, in which all instruments were introduced. The familiarization was done twice, 1 week before the first real test; (2) assessment in a 3-h postprandial state and (3) athletes were instructed not to use diuretics during 7 days before the test and not to ingest alcoholic drinks, coffee, energy drinks, and tea on the previous day of the test; (4) it was suggested that the subjects should urinate 30 min before the test. The laboratory and field tests were performed with a minimum interval of 48 h.

Ethical Approval

The risks and benefits of the research were put on view, and each subject signed the Free and Informed Consent Term (FICT) and, in the case of children under the age of 18, the Free and Informed Assent Term (FIAT). The experimental model was approved by the Ethics Committee of São Judas University – protocol number 37500414.4.0000.0089.

Participants

Twenty male competitive athletes from an under-17 national soccer team were analyzed during the competitive period. The evaluated subjects had a minimum experience of 3 years in the modality and the average daily training time of 2 h. The average age was 16.40 ± 0.68 years; stature: 175.45 ± 9.0 cm; total body mass: 66.4 ± 7.75 kg; percentage of body fat: 12.4 ± 3.31%; fat free mass: 58.2 ± 7.30 kg; maximum oxygen consumption of 60.8 ± 4.36 ml/kg/min.

The inclusion criteria were: (1) to practice competitive soccer, with a minimum of 1 h 30 m training per day, 5 days a week; (2) to have a 3-year minimum experience in soccer practice; (3) non-smoking. Exclusion criteria were: (1) athletes with recent (until 6 months before the tests) osteo-myo-articular lesion which could prevent the execution of physical tests; (2) with clinical counter indication, which would prevent the performance of stress tests; (3) who were in the process of rehabilitation; (4) who play soccer as goalkeeper.

Cardiorespiratory Test

In order to perform the maximal incremental cardiopulmonary test (MICT) with gas exchange analysis, the following protocol was selected: 3-min stimulus and 1-min of passive recovery. The initial speed of the treadmill and the respective increments per stage were: 6 km/h and 1 km/h, respectively. Regarding the protocol of the field test, the Yo-Yo Intermittent Recovery was selected with the correction especially designed for soccer athletes suggested by Castagna et al. (2006).

Ventilatory data, including the oxygen consumption (VO_2) and the percentage of maximal oxygen consumption ($\%VO_{2max}$) were collected by the gas analyzer. The equipment was calibrated by the closed loop system. The volume sensor was calibrated using a 3L calibration syringe (Hans Rudolph). The syringe was manually handled in order to produce a flow from 0.4 to 12 L/s. The O2 and CO2 sensor was calibrated using the standard compound gas of 11.97% O2 and 4.95% original CO2, as certified by the manufacturer. The Ventilation during the test occurred through the VacuMed® mouthpiece, with a nasal clip locking, just so the air would not be allowed to escape through the cavity. HR and percentage of maximal heart rate ($\%HR_{max}$) were measured during the test, and at the end of each stage for control. The blood lactate concentration was measured at the end of each stage in both tests. The temperature and relative humidity of the laboratory were controlled between 22–25°C and 50–60%, respectively.

The VT was estimated at the point where the intensity of running caused the first rise in the ventilatory equivalent of oxygen (VE/VO_2) without a concurrent rise in the ventilatory equivalent of carbon dioxide (VE/CO2). On the other hand, the respiratory compensation point was identified by the sudden increase in the VE/CO2, according model proposed by Skinner and McLellan (1980).

During both laboratory test and field test, the rating of perceived exertion was identified by three different instruments at the end of each stage: Borg's Ratings of Perceived Exertion 6 – 20 (Borg, 1998); Cavasini Scale (Cavasini and Matsudo, 1993); GOAL scale. Due to the details of the images, The GOAL Scale was printed on canvas in follow dimensions: 80 cm (width) × 23 cm (height). Each image on the scale was 13 cm wide × 15 cm high. The other scales were presented in laminated paper in the dimensions of 297 mm (width) × 420 mm (height).

The mouthpiece, used for gas analysis, hindered verbal communication during the test, so the athletes were instructed to point the correct anchoring of the presented instruments with their index finger of their dominant hand. The evaluator had been properly trained for the application of the test, which made it easy to observe the athlete and the classifications pointed out by them in the passive recovery periods.

Prior to the start of the test, the researchers had made the following recommendation: "We would like you to stay on the treadmill during the 3-min stimulus periods." During the passive recovery, we would like you to put your feet on the siders and stand still. Please, use the numbers and expressions of these two scales (Borg and Cavasini Scale) as well as the numbers and images of the GOAL Scale to tell us what your body perception is during the stimulus. Look at the first image where the player is just starting the game. If you feel like this player while walking/running, your effort perception will be classified as minimal, equivalent to the number one. Now, look at the last image of this instrument. If you feel like this player instead, your perception of effort will be classified as maximum, equivalent to number six. If you feel as somewhere between the first and the last cartoon, point the image and the number which best corresponds to your level of effort.

In order to avoid some physiological interference from dehydration, the athletes ingested 5–10 ml/kg of body weight of sports drink 2 h before the test, following the ACSM Position Stand (Thomas et al., 2016).

Instruments and Materials

The rate of oxygen consumption was measured breath by breath using an automatic ergospirometry system (V_{max} Encore 29c computerized system, SensorMedics® VIASYS Healthcare Inc., Yorba Linda, CA, United States). The heart rate was measured at the end of each stage of both maximal tests using the RC3 GPS heart rate monitor, Polar® (Kempele, Oulu, Finland).

The blood lactate concentration was determined by the use of the ROCHE® Accutrend Plus equipment. Right at the end of each stage, the perforation of the digital pulp finger was performed, after adequate hygiene. A total of 40 microliters of blood was collected and poured into the reagent strips for the determination of [La]. Blood collection was done, in both maximal tests, by using heparinized capillaries (G100CCH, Glasscyto®) with 80 IU/ml of sodium heparin in order to better standardize the amount of blood in each strip. Both the lactate analyzer and the ergospirometry system were calibrated according to the manufactures' specifications.

Data Analysis and Statistics

The anthropometric, physiological, performance, and perceptual variables were calculated from average and standard deviation. The Shapiro–Wilk normality test was applied in order to define parametric and non-parametric variables, and their results culminated in the choice of Spearman's linear correlation (non-parametric samples). The significance level of $p < 0.01$ was adopted in all cases. The tests were conducted by using the statistical package GraphPad Prism for Mac. The values related to the correlation force were classified according to the Hopkins et al. (2009).

RESULTS

All data presented are derived from 20 soccer players **Figure 2** shows the final version of The GOAL Scale after the judges' considerations, in which it is possible to highlight: changes in ventilation signs in the different phases of exercise; biomechanical changes, including the angle of knee extension as well as the degree of trunk flexion; the incorporation of numeric anchorages in each image; as well as the use of neutral colors in the uniforms of the cartoons, thus contributing to the universalization of the instrument (**Figure 2**).

Outlines the values of $\%HR_{max}$, $\%VO_{2max}$, Borg RPE 6 – 20, velocity and Cavasini Scale in each anchorage of GOAL Scale during both tests (MICT and Yo-Yo Intermittent Recovery Test – Level 1) (**Table 1**).

The correlation values among the GOAL Scale, the physiological variables (HR, %HRmax, VO_2 e VO_{2max}), and the psychophysical variables (RPE identified by different instruments) measured during MICT were: Borg RPE Scale 6 – 20 ($r = 0.93$); Cavasini Scale ($r = 0.91$); treadmill speed ($r = 0.91$); blood lactate concentration ($r = 0.68$); heart rate ($r = 0.87$); heart rate percentage ($r = 0.91$); oxygen consumption ($r = 0.89$) and oxygen consumption percentage ($r = 0.91$). All the correlation analysis was statistically significant ($p < 0.01$).

The construct validity of GOAL Scale during the maximal cardiopulmonary effort test, using the relationship among the scores measured on the Borg RPE Scale 6 – 20, Cavasini Scale and the GOAL Scale is demonstrated in **Figure 3**.

The concurrent validity of GOAL Scale during the maximal cardiopulmonary effort test, using the relationship among the scores measured on the GOAL and the respective values measured in physiological parameters is demonstrated in **Figure 4**.

The correlation values into GOAL Scale and other physiological and psychophysical variables measured during the field test were: Borg RPE Scale 6– 20 ($r = 0.88$); Cavasini Scale ($r = 0.90$); stage speed ($r = 0.89$); blood lactate concentration ($r = 0.83$); heart rate ($r = 0.83$); heart rate percentage ($r = 0.86$); oxygen consumption ($r = 0.88$) and oxygen consumption percentage ($r = 0.83$). All the correlation analysis was statistically significant ($r < 0.01$).

The construct validity of GOAL Scale during the field test, using the relationship among the scores measured on the Borg RPE Scale 6–20, Cavasini Scale and the GOAL Scale is demonstrated in **Figure 5**.

The concurrent validity of GOAL Scale during the Yo-Yo Intermittent Recovery Test – Level 1, using the relationship among the scores measured on the GOAL and the respective

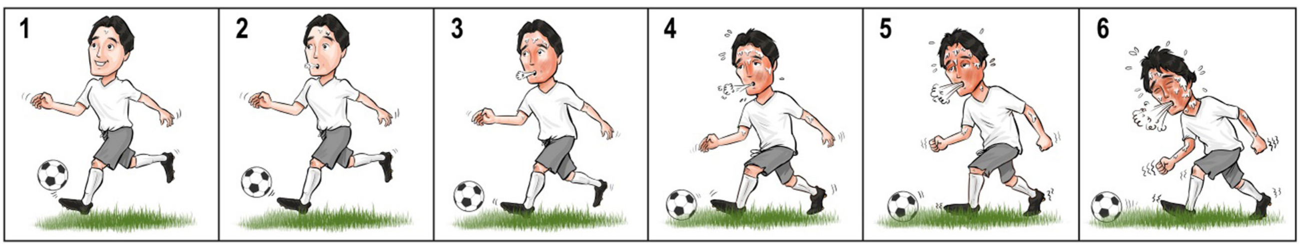

FIGURE 2 | GOAL Scale. Patent registration: BR 20 2018 072989 1.

TABLE 1 | Values of psychological and physiological variables during maximal tests.

	Test	GOAL 1	GOAL 2	GOAL 3	GOAL 4	GOAL 5	GOAL 6
HR (bpm)	MICT	115.0 ± 17.0	141.0 ± 15.0	159.0 ± 16.0	173.0 ± 12.0	184.0 ± 10.0	190.0 ± 11.0
	Yo-Yo IRT1	134.0 ± 19.0	161.0 ± 20.0	180.0 ± 10.0	189.0 ± 13.0	192.0 ± 12.0	195.0 ± 10.0
$\%HR_{max}$	MICT	59.3 ± 8.5	73.0 ± 6.8	82.7 ± 7.0	90.3 ± 4.8	96.2 ± 3.2	99.0 ± 1.8
	Yo-Yo IRT1	70.4 ± 11.0	82.4 ± 10.8	93.0 ± 6.0	96.0 ± 3.2	98.9 ± 1.2	99.9 ± 0.1
RPE 6–20 (AU)	MICT	7.0 ± 1.0	9.0 ± 1.0	11.0 ± 1.0	14.0 ± 2.0	16.0 ± 2.0	19.0 ± 1.0
	Yo-Yo IRT1	7.0 ± 2.0	9.0 ± 2.0	11.0 ± 2.0	13.0 ± 2.0	16.0 ± 2.0	19.0 ± 1.0
Cavasini (AU)	MICT	1.0 ± 1.0	3.0 ± 1.0	4.0 ± 1.0	6.0 ± 1.0	8.0 ± 1.0	9.0 ± 1.0
	Yo-Yo IRT1	1.0 ± 1.0	3.0 ± 1.0	4.0 ± 2.0	6.0 ± 1.0	7.0 ± 1.0	9.0 ± 1.0
Blood Lactate (mmol/L)	MICT	2.1 ± 0.8	2.3 ± 1.0	2.8 ± 1.2	3.9 ± 1.8	6.2 ± 2.5	8.6 ± 2.8
	Yo-Yo IRT1	2.1 ± 1.0	3.6 ± 2.0	5.4 ± 2.9	8.0 ± 3.2	10.8 ± 4.2	13.9 ± 3.5
VO_2 (ml/kg/min)	MICT	20.3 ± 5.4	32.1 ± 8.2	43.5 ± 7.6	49.9 ± 7.1	56.3 ± 6.4	60.8 ± 4.4
	Yo-Yo IRT1	37.6 ± 1.1	40.5 ± 3.4	44.0 ± 5.4	48.9 ± 3.1	52.4 ± 3.4	54.7 ± 2.8
$\%VO_{2max}$ (ml/kg/min)	MICT	33.1 ± 8.6	52.2 ± 12.9	71.3 ± 12.0	81.4 ± 9.0	92.7 ± 6.2	99.2 ± 1.5
	Yo-Yo IRT1	69.2 ± 3.9	73.1 ± 7.0	79.9 ± 10.8	87.5 ± 4.9	94.5 ± 4.1	98.9 ± 1.7
Velocity (km/h)	MICT	7.0 ± 1.0	9.0 ± 1.4	11.0 ± 1.5	13.0 ± 1.4	14.6 ± 1.4	16.0 ± 1.4
	Yo-Yo IRT1	12.0 ± 1.5	13.7 ± 1.2	14.9 ± 0.7	15.6 ± 0.6	16.3 ± 0.7	16.8 ± 0.5

HR, heart rate; $\%HR_{max}$, percentage of maximal heart rate; RPE 6–20, Rating of Perceived Exertion 6–20 Borg Scale; VO_2, oxygen consumption; $\%VO_{2max}$, percentage of maximal oxygen consumption; MICT, maximal incremental cardiopulmonary test; Yo-Yo IRT 1, Yo-Yo Intermittent Recovery Test Level 1; AU, Arbitrary Units; GOAL 1, GOAL Scale Anchorage 1; GOAL 2, GOAL Scale Anchorage 2; GOAL 3, GOAL Scale Anchorage 3; GOAL 4, GOAL Scale Anchorage 4; GOAL 5, GOAL Scale Anchorage 5; GOAL 6, GOAL Scale Anchorage 6.

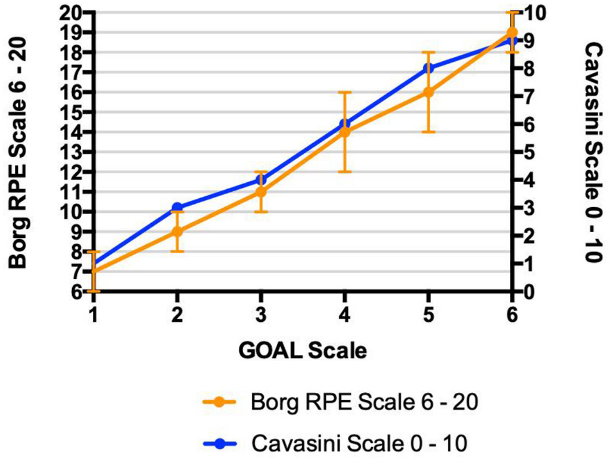

FIGURE 3 | Maximal cardiopulmonary effort test – Construct validation values of Borg RPE Scale and Cavasini Scale for each value of GOAL Scale. Relationships among rating of perceived exertion identified by three different instruments (GOAL Scale, Borg RPE Scale, and Cavasini Scale) during maximal incremental cardiopulmonary test; • *r2* = 0.86; • *r2* = 0.83.

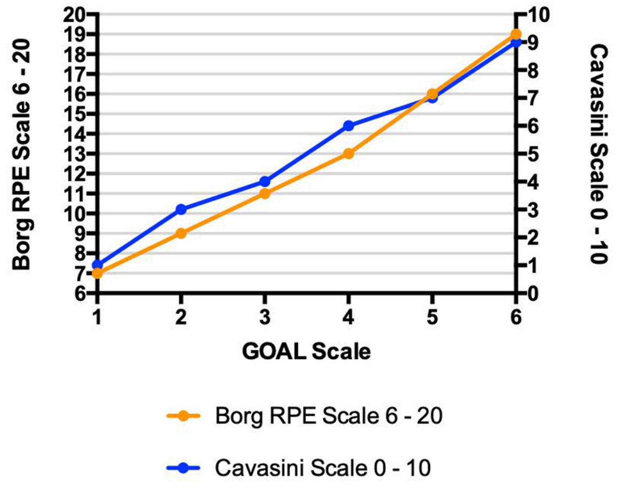

FIGURE 5 | Yo-Yo Test – Construct Validation Relationships among rating of perceived exertion identified by three different instruments (GOAL Scale, Borg RPE Scale, and Cavasini Scale) during Yo-Yo Intermittent Recovery Test – Level 1; • *r2* = 0.77; • *r2* = 0.81.

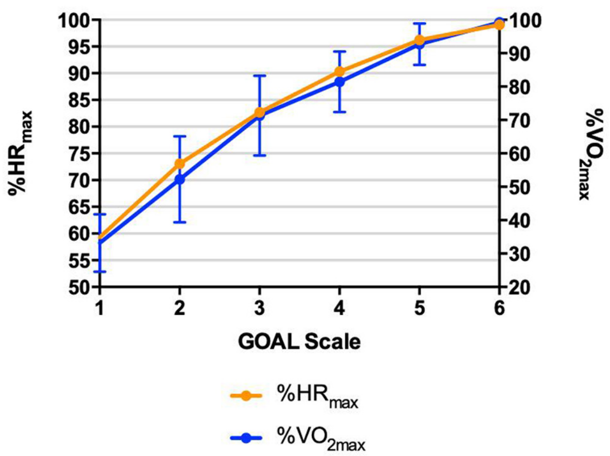

FIGURE 4 | Maximal cardiopulmonary effort test – Concurrent validation relationships among rating of perceived exertion identified by GOAL Scale and physiological parameters (heart rate percentage – $\%HR_{max}$ and oxygen consumption percentage – $\%VO_{2max}$) during maximal incremental cardiopulmonary test; • *r2* = 0.83; • *r2* = 0.83.

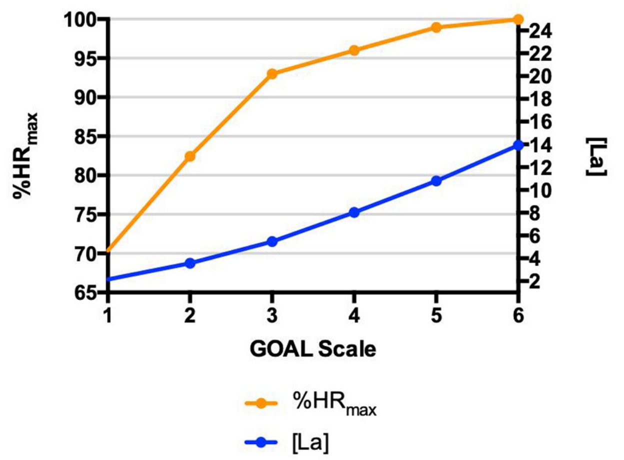

FIGURE 6 | Yo-Yo Test – Concurrent Validation Relationships among rating of perceived exertion identified by GOAL Scale and physiological parameters (heart rate percentage – $\%HR_{max}$ and blood lactate concentration) during Yo-Yo Intermittent Recovery Test – Level 1; • *r2* = 0.73; • *r2* = 0.69.

values measured in physiological parameters is demonstrated in **Figure 6**.

In order to prescribe training sessions is very important to know the ventilatory threshold (VT) and respiratory compensation point (RCP) and the corresponding values of perceived exertion. (**Table 2**) shows the values of different instruments of perceived exertion which corresponding with the VT and RCP. The **Figure 7** shows the agreement between the Borg 6 –20 scale and the GOAL scale at ventilatory threshold and respiratory compensation point during cardiorespiratory test.

As the frequency of use of the anchorages of each instrument was evaluated, in the TECM and in the Yo-Yo Intermittent Recovery Test – Level 1, the results found were, respectively: 94.2 ± 11.18% and 89.2 ± 15.56% of the total of the GOAL Scale anchorages (six in all); 76.8 ± 14.89% and 64.1 ± 15.18% of the total of the Cavasini Scale (11 in all); 58.7 ± 12.35% and 49.7 ± 12.70% da Borg 6 – 20.

DISCUSSION

The aim of this research was to elaborate and to validate a specific pictorial perceived exertion scale for soccer players. The validity process used in this research has verified the association into RPE values found by GOAL Scale and the

TABLE 2 | Ventilatory threshold and respiratory compensation point and their corresponding variables.

Variable	MICT RCP	MICT VT	Yo-Yo IRT1 RCP	Yo-Yo IRT1 VT
GOAL	3.0 ± 1.0	4.0 ± 1.0	2.0 ± 1.0	3.0 ± 1.0
RPE 6–20	11.0 ± 2.0	13.0 ± 2.0	9.0 ± 2.0	10.0 ± 2.0
CAVASINI	4.0 ± 1.0	5.0 ± 2.0	2.0 ± 2.0	1.0 ± 2.0
$\%HR_{max}$	80.8 ± 3.8	89.4 ± 3.1	80.4 ± 4.3	88.8 ± 4.3
$\%VO_{2max}$	68.0 ± 6.8	80.5 ± 4.1	71.2 ± 3.6	76.4 ± 3.9
[La]	2.3 ± 0.9	3.5 ± 1.0	2.5 ± 1.0	3.7 ± 1.4

GOAL, GOAL Scale; RPE 6–20, Rating of Perceived Exertion 6–20 Borg Scale; CAVASINI, Cavasini Scale; $\%HR_{max}$, percentage of maximal heart rate; $\%VO_{2max}$, percentage of maximal oxygen consumption; [La], blood lactate concentration; MICT RCP, respiratory compensation point in the maximal incremental cardiopulmonary test; MICT VT, ventilatory threshold in the maximal incremental cardiopulmonary test; Yo-Yo IRT 1 RPC, respiratory compensation point in the Yo-Yo Intermittent Recovery Test Level 1; Yo-Yo IRT 1 VT, ventilatory threshold in the Yo-Yo Intermittent Recovery Test Level.

other physiological and psychophysiological variables during laboratory and field progressive tests. The results showed significant correlation values which make it able to demonstrate the validity of the instrument and, from this reality, to suggest its use as an intensity control instrument on athletes of this modality.

On the other hand, it is necessary to highlight the non-linear relationship among GOAL Scale and physiological variables that was found. According to Stevens (1956) and psychophysical power law, sensations grow as a power of stimulus that is different according to different types of stimulus (Gescheider, 1997). Thusly, the increase in the perceptual response to growing stimuli of work rate, when it is related with physiological (and objective) parameters (cited above) has been known to follow a non-linear path (Borg et al., 1987; Pincivero et al., 2003).

In the scientific validity of RPE Borg scale (instrument most frequently discussed in the scientific literature), the association with objective physiological variables (heart rate and oxygen consumption) was evaluated in 40 healthy subjects, which supports the method used in the instrument validation for soccer players (Borg and Kaijser, 2006), in which the results demonstrated positive association between the rating of perceived exertion, identified by GOAL Scale, HR, $\%VO_{2max}$, [La], RPE (identified by Borg and Cavasini Scale), in both tests (laboratory and field). The ratings and heart rates were recorded every minute and blood lactates every third minute during the work tests.

In attempt to elaborate more specific instruments, perceived exertion OMNI scales were validated for different sports and publics, including resistance training (Robertson et al., 2003), cycloergometer training (Robertson et al., 2004) and training for children (Robertson et al., 2005). Similarly to what was performed in Borg's study and in GOAL scale validation, the studies mentioned above also used the correlational method (between objective and subjective parameters) for measurement of instruments' scientific validity. Recently, Micklewright et al. (2017) developed and validated the Fatigue Classification Index, instrument elaborated from numerical, verbal, and diagrammatic anchorages which has the purpose to evaluate the perceived fatigue. The authors carried out four experiments involving eighteen healthy adult males, similarly to the present research. Another point is that the authors analyzed the same physiological variables that were analyzed in the present research, including: heart rate, breath-by-breathe ventilation and gas measurements and blood lactate concentration, which confirm the validity of these variables as objective variables in order to confirm the validity of the effort subjective variables through their relationship.

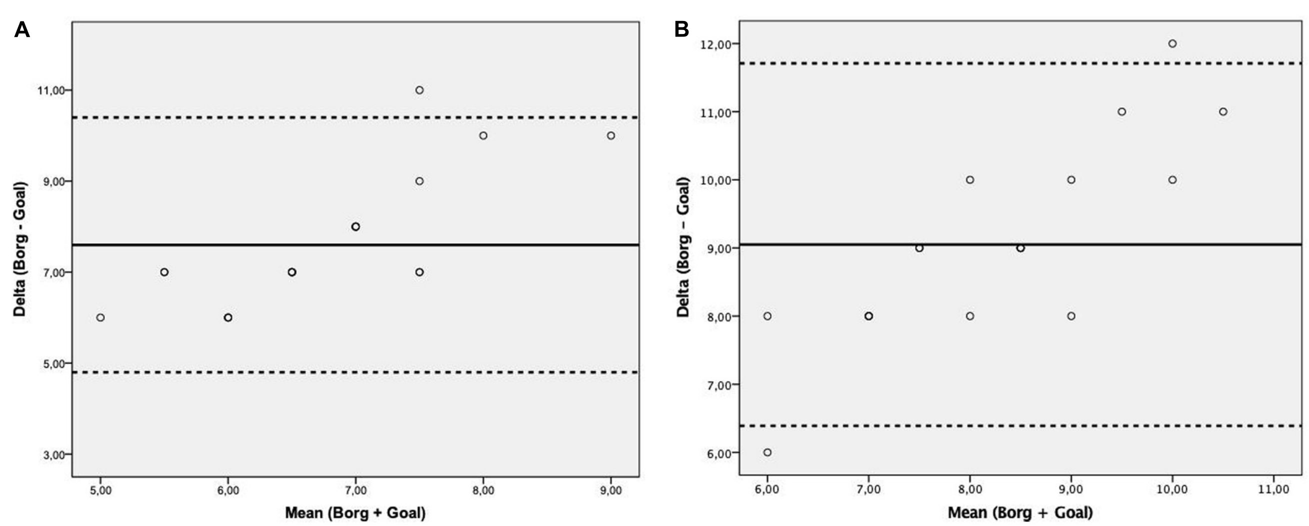

FIGURE 7 | Bland-Altman plot assessing the agreement between the Borg 6–20 scale and the Goal scale at ventilatory threshold **(A)** and respiratory compensation point **(B)** during cardiorespiratory test. Solid line represents the mean difference (bias) between Borg 6–20 and Goal scale. Upper and lower dashed lines represent the 95% limits of agreement (mean difference ± 1.96 × standard deviation of the difference).

The perceived exertion is a variable frequently used to monitor the training load which the soccer athletes (indoor and field) are submitted to throughout a season (Impellizzeri et al., 2005; Casamichana et al., 2013; Moreira et al., 2013). It is possible to affirm that one great advantage of this instrument is its sensibility to different parameters which are present in all training programs, including intensity (Connolly and Tenenbaum, 2010; Bourdon et al., 2017), volume, exercise type (Thorpe et al., 2016), level of involved participants and their psychological attributes (Hutchinson et al., 2008). Following this train of thought, Gaudino et al. (2015) evaluated twenty-two elite players competing in the English Premier League, and showed that volume variables (sprints and the number of contacts and acceleration actions) can exert straight influence on the RPE values signaled by the soccer players. Therefore, it is possible to affirm that the perceived exertion is a variable which is sensible to different workouts organization and that it can integrate both physiological and psychological variables, still respecting the players' individuality.

In spite of the fact that the RPE is the most frequently used instrument to measure the effort in soccer and futsal players, Polito et al. (2017) highlighted that the subjective data achieved with its use should be continuously associated with other objective measured parameters during all season, including heart rate, blood lactate concentration, traveled distance, number of contacts in plyometric training, which promote the guarantee of a better data interpretation by physical trainers, coaches and psychologists aiming a greater (re)orientation of the training sessions. Analyzing a professional female futsal team over 45 sessions, Milanez et al. (2014) evaluated the relationship between the internal training load (calculated by the perceived exertion method) and salivary immunoglobulin A (SIgA) and the data found shows that the training load above 435 AU (arbitrary units) is associated with decrease of immunity, providing one more possible use of the perceived exertion in this sport.

However, despite the strong consistence of the perceived exertion instruments, Impellizzeri et al. (2011) asked attention to three different situations, in which the RPE could present greater intersubjective variability: (1) when developed without psychophysical proceedings needed; (2) when modified without proper care to keep the original characteristics of the instrument, especially during the translation process; (3) when proper correspondence with exercise intensity indicators is not shown.

Therefore, the simple translation of perceived exertion scales to different languages without the proper methodological proceedings (cross-cultural validation, for example), which allows the maintenance of its original properties, is a risk for its validity and for the collected data obtained from it as well, which can be avoided with cartoon scales.

Another factor observed in the present research was the relationship between the cartoons and the anaerobic thresholds, by using the Multiple Threshold Model in different exercise phases as proposed by Skinner and McLellan (1980). The results showed that the cartoons numbers 3 and 4 of GOAL Scale corresponded, respectively, to thresholds 1 and 2 in MICT. On the other hand, in the field test, the first and second threshold were related to the cartoons numbers 2 and 3 of GOAL Scale, respectively. It was found the same trend for the other scales, which demonstrated greater values to the same relative submaximal load in MICT when compared to the field test, which can be reinforced by the scientific literature, which affirms greater RPE values in laboratorial conditions, as these conditions are less specific situations to the real practice of the sports in general (St Gibson et al., 2006). These findings contribute to the understanding of the sensibility showed by athletes in perceived exertion identification in different situations.

Some noteworthy limitations must be addressed when interpreting or applying these results: (1) the study only evaluated the application of the GOAL Scale to measure the perceived exertion of soccer athletes in different maximal effort tests, therefore, special care is needed when using the GOAL Scale for other sports and for other variables before testing it; (2) the interrelationships between the different anchors of the scale were not evaluated, which should be the next researches involving this pictorial instrument.

The perception of effort is an essential variable to measure the loads applied during the training program for soccer, futsal and beach soccer players. In order to avoid the wrong translation by players of different languages, or misinterpretation by players of different literacy levels, the GOAL Scale is a good alternative to be applied to athletes of these modalities.

This research provides firm support for the use of the GOAL Scale as an instrument able to estimate the intensity of effort that the beach soccer, futsal, and soccer players realize through subjective perception, contributing with the effort intensity control. It is suggested that the next steps would be the reliability evaluation of the GOAL Scale, and the use of the GOAL Scale in the real context of the beach soccer, futsal and soccer games, identifying how the data provided by this instrument relates to the external load indicators.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Comitê de Ética em Pesquisa Universidade São Judas Tadeu. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

LP and MB conceived the original idea of the study. MV selected the researches and contributed to data processing and analysis. LP and DM analyzed and presented the data. LP and MM wrote and organized the manuscript. All authors reviewed the document and approved the final version for submission.

FUNDING

This work was conducted during a scholarship supported by CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazilian Federal Agency for Support and Evaluation of Graduate Education within the Ministry of Education of Brazil. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

ACKNOWLEDGMENTS

The authors specially thank Prof. Gunnar Borg, Ph.D. (in memoriam) and Prof. Elisabet Borg, Ph.D. for their valuable comments on this research. The authors also thank Prof. Marcelo de Mesquita Spinola for his assistance in the data collecting and analysis.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 12 January 2021
doi: 10.3389/fpsyg.2020.621763

Physiological and Anthropometric Determinants of Performance Levels in Professional Futsal

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OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 26 October 2020
Accepted: 14 December 2020
Published: 12 January 2021

Citation:
Sekulic D, Pojskic H, Zeljko I, Pehar M, Modric T, Versic S and Novak D (2021) Physiological and Anthropometric Determinants of Performance Levels in Professional Futsal. Front. Psychol. 11:621763. doi: 10.3389/fpsyg.2020.621763

There is an evident lack of studies examining the pursuit of excellence in futsal. The aims of this study were to evaluate anthropometric and physiological variables that may contribute to distinguishing among performance levels in professional futsal players and to evaluate correlates of those variables. The participants were 75 male professionals (age = 25.1 ± 5.1 years, body height = 182.3 ± 6.2 cm, body mass = 80.8 ± 10.4 kg), who were divided into performance levels using two criteria: (i) starters (first teams) vs. non-starters (substitutes) and (ii) top-level players (members of the national team and players who participated in top-level team competition in Europe) vs. high-level players (team players competing at the highest national competitive rank). Variables included anthropometrics (body height and mass, BMI, body fat percentage), generic tests of physiological capacities [5- and 10-m sprints, countermovement jump, broad jump, 20-yard test, reactive strength index (RSI)], and futsal-specific fitness tests [kicking speed by dominant and non-dominant leg, futsal-specific tests of change of direction speed, and reactive agility (FSRAG) involving/not involving dribbling the ball]. Top-level players outperformed high-level players in RSI, broad jump, kicking speed, and FSRAG involving dribbling. Starters achieved better results than non-starters in fewer variables, including kicking speed and RSI. Body fat percentage negatively influenced FSRAG involving dribbling, and RSI. FSRAG, RSI, and kicking speed were significantly correlated, indicating the similar physiological background of these capacities. The findings suggest that enhanced reactive strength and the ability to rapidly change direction speed in response to external stimulus while executing futsal-specific motor tasks (e.g., dribbling), along with players' ability to kick the ball speedily, can be considered essential qualities required for advanced performance in futsal. Consequently, futsal strength and conditioning training should be targeted toward lowering relative body fat, maximizing lower-body reactive strength and including futsal-specific skills (e.g., dribbling, shooting) in reactive agility drills.

Keywords: conditioning capacities, kicking speed, reactive agility, change of direction speed, team sports, fitness level, reactive strength index

INTRODUCTION

Futsal is a high-intensity intermittent sport that requires players to repeatedly engage in sequences of intense activities (e.g., sprinting, changes of direction, acceleration, deceleration kicking) on the futsal court (Spyrou et al., 2020). During the match, futsal players cover 3000–4500 m (Barbero-Alvarez et al., 2008), and 26% of the total distance covered is performed at a high-intensity level (Doğramacı and Watsford, 2006), with approximately 26 sprints per match (Caetano et al., 2015). Additionally, recent studies reported cardiovascular stress higher than 85% of maximum heart rate (HRmax) during more than 80% of actual playing time (Ayarra et al., 2018), with players reaching HRmax in most of the matches (Trabelsi et al., 2014). Moreover, several studies reported the blood lactate concentration to be over the lactate threshold (>4.0 mmol L^{-1}) during futsal matches (Milioni et al., 2016; Dos-Santos, 2020). Accordingly, futsal requires a high level of energy from both the anaerobic and aerobic systems (Castagna and Alvarez, 2010). Furthermore, well developed speed, agility, muscle strength and power are important in execution of specific futsal performances (e.g., shooting, dribbling, passing, ball recovery) and movements (e.g., accelerations, decelerations, sprints, change of directions, jumps) (Young et al., 2002; Alvarez et al., 2009; Castagna et al., 2009; Junior et al., 2017; Ribeiro et al., 2020) and consequently, they are considered to be key indicators of overall performance in futsal matches (Galy et al., 2015; Junior et al., 2017).

Studies already attempted to describe the physiological characteristics of futsal players across the competitive levels and age groups (Junior et al., 2017). For example, Alvarez et al. (2009) investigated aerobic fitness in futsal players of different competitive levels and noted that VO2max may be considered a competitive-level dependent physical variable in futsal. Pedro et al. (2013) reported that running speeds at the ventilatory threshold and maximal oxygen consumption discriminate the competitive futsal level, with better performance in higher performance-levels. Nakamura et al. (2016) investigated differences in physical performance between U-20 and senior top-level Brazilian futsal players and reported that long-term exposure to futsal may lead to improvement in aerobic fitness and cardiac autonomic regulation while impairing the muscle power and speed performance. Recently, Sekulic et al. (2019) highlighted the importance of agility in identifying the performance levels of professional futsal players using newly developed tests of the change of direction speed (CODS) and reactive agility (RAG) in competitive futsal players. Finally, literature indicates that performance levels of futsal players differ in match running performances. In brief, 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 (Spyrou et al., 2020).

It is widely accepted that anthropometric characteristics might be an important correlate of physical performance and factor of success in sport (Rienzi et al., 2000). For example, several studies suggested that high body mass and body fat measurements were related to poor muscle power in soccer (Nikolaïdis, 2012), basketball (Nikolaidis et al., 2015), and handball (Nikolaidis and Ingebrigtsen, 2013) players. On the other hand, anthropometric characteristics of futsal players have not been frequently investigated. In particular, Nikolaidis et al. (2019) examined the relationship between age and body mass status with field and laboratory measures of physical fitness in Greek futsal players at different age levels and concluded that the prevalence of overweight in futsal players should be an important concern for practitioners working in this team sport. Galy et al. (2015) assessed the anthropometric and physiological characteristics of Melanesian futsal players and found significant correlation between body height and countermovement jump (CMJ) performance. Recently, López-Fernández et al. (2020) investigated bilateral asymmetries between elite (1st league) and sub-elite (3rd league) male futsal players, and noted significant bilateral asymmetry in fat-mass percentage between dominant and non-dominant limbs for sub-elite players.

Although physiological and anthropometric characteristics of futsal players were extensively investigated, only few studies have focused on different competitive levels. These comparative analyses are important because they reveal physiological and anthropometric factors that differentiate players at different competitive and expertise levels (Naser and Ali, 2016). Specifically, Jiménez-Reyes et al. (2019) indicated 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. Further, Ayarra et al. (2018) reported no significant differences in either acceleration capacity (5 and 15 m) or CODS ability between third and second division and junior players. However, those researchers found players competing at a higher playing level to have better jumping and sprinting abilities (Ayarra et al., 2018). Similarly, Naser and Ali (2016) reported that first division players were faster than amateur players over a 5 m distance.

The rationale of this study comes from the lack of knowledge of determinants of performance-level differences in professional futsal. More specifically, although, previous studies provided important insights into the physiological and anthropometric characteristics required to play at different competitive levels, it is evident that most of the previous investigations evidenced differences between relatively diverse performance levels (Naser and Ali, 2016; Ayarra et al., 2018; López-Fernández et al., 2020). In other words, only few studies determined the differences between performance groups by examining the pursuit of excellence, while to the best of our knowledge, no study has examined this issue in international samples. Supportively, in a very recent review paper examining the characteristics of the futsal demands and players' characteristics authors noted that little is known regarding elite and sub-elite futsal players' neuromuscular abilities (i.e., strength, jumping, sprinting, and change of direction) (Spyrou et al., 2020). This issue is particularly important for creating the profiles of players that can respond to the physical demands of the highest competition levels (i.e., champions' league or national team competitions).

The main objectives of this study were to identify the fitness status and performance-level differences in an international sample of professional futsal players. Additionally, we studied the correlates of the most important fitness parameters in the studied players. An understanding of these characteristics is expected to be beneficial for coaches in the selection of players that are better suited to the highest competition levels. Originally, we hypothesized that fitness variables will be significant determinants of performance levels in professional futsal.

MATERIALS AND METHODS

Participants

The sample included 75 male professional futsal players (age = 25.1 ± 5.1 years, body height = 182.3 ± 6.2 cm, body mass = 80.8 ± 10.4 kg) from seven futsal teams competing at the highest national level in Croatia, and Bosnia and Herzegovina (including the national champions in both countries for the preceding season). The participants were selected based on the following criteria: minimum 7 years of active involvement in futsal, older than 18 years of age, free from injury or illness, and regular performance of standard training for at least 3 weeks prior testing. The goalkeepers were not included in this investigation. For the purpose of this study, the total sample was divided into performance groups based on two criteria. The first criterion included clustering according to their status in the team, and thus players were identified as "starters" (i.e., first team; n = 35), and "non-starters" (i.e., substitutes; n = 40). This division was carried out by the head coach of each team. The second performance level clustering also included two performance levels, but players were observed as (i) top-level players (17 players) and (ii) high-level players (58 players). The top-level players were those who met at least one of the three following criteria: (1) they were members of senior-level national futsal team over the last 2 years; (2) they were members of the junior-level national futsal in the last competitive season (<18 years); and (3) they participated in the Union of European Football Association (UEFA) Futsal Champions League over the last 2 years, which is the highest competition level for futsal teams in Europe. The high-level players were those who were not grouped as the top-level players. All participants were tested over 3 weeks in September 2019 at the beginning of the competitive season. In this period, they trained 10–12 h (5–6 × ∼2 h) on the court to improve technical and tactical skills and 3 h (2 × ∼1.5 h) off-court in the gym to improve speed, strength and power.The participants were asked to refrain from any high intensity activity, tobacco, alcohol, and caffeine use and sleep deprivation for at least 2 days before the testing sessions. To stay properly hydrated, participants were allowed to drink water *ad libitum* in small amounts in each testing session.

The ethics board of the first author's institution provided approval for the research experiment (Ethical Board Approval No: 2181-205-02-05-14-001). All participants were informed of the purpose, benefits and risks of the investigation. The participants voluntarily took part in the testing after they provided written consent. Sample size was estimated *a priori* using means and SDs from previous studies intended to evaluate the fitness status of professional level futsal players (Sekulic et al., 2019). Using G-Power software (version 3.1.9.2; Heinrich Heine University Dusseldorf, Dusseldorf, Germany), were estimated that 67 subjects would provide an appropriate sample size for paired-samples differences ($p \leq 0.05$, power = 0.80).

Procedures

Participants attended one familiarization session and two testing sessions. At the beginning of the familiarization session, the participants answered questions about their age, training, and health status and playing experience and level. Afterwards participants were familiarized to the physical capacity tests with special attention being paid to the futsal-specific agility tests (see details below). On the first testing day, anthropometrics were measured and CMJ, standing broad jump (SBJ), reactive strength index (RSI), sprinting over 5 and 10 m and the 20-yard generic CODS test (20 yards) were performed. On the second day, kicking speed with the dominant leg (Kicking-D) and non-dominant leg (Kicking-ND) was assessed, and the newly developed futsal-specific reactive agility RAG and futsal-specific CODS tests were performed. To minimize the variation in climatic and other conditions and to avoid diurnal variation all tests were performed in a sport hall on a parquet floor between 8:00 and 11:00. Prior to the assessment, participants performed standardized warm-up that included a 5-min self-paced running, followed by 5 min of dynamic stretching (e.g., high knees, lunges) and 5 min of futsal-specific high-intensity exercises (e.g., sprints and changes of direction speed with and without the ball). The rest between tests performed on the same day was standardized to 5–6 min.

Variables

The anthropometric variables were measured with Seca stadiometers and scales (Seca, Birmingham, United Kingdom) and skinfold calipers (Holtain, London, United Kingdom) and included body height, body mass, and percentage of body fat (BF%). Body height (cm) was measured in bare feet to the nearest 0.1 cm. BMI was calculated by dividing body mass (m) by the squared body height (in meters). The BF% was calculated using body density (BD) according to the following formula: BD = 1.162–0.063 × log Σ4SF (where Σ4SF = sum of the biceps, triceps, subscapular, and suprailiac skinfolds). Body density was converted to body fat percentage: BF% = (4.95/BD−4.5) × 100 (Pehar et al., 2018).

The jumping abilities were estimated with the CMJ, SBJ, and RSI. The CMJ test was assessed with an Optojump system (Microgate, Bolzano, Italy), and the test is characterized by the stretch and shortening pattern of muscle function (Della Corte et al., 2020). In this test, the participant performs a maximum upward vertical jump after moving downward from an upright starting position with hands placed on the hips. In the SBJ, participants stand with their feet on the marked spot on the measuring scale (ELAN, Begunje, Slovenia). The length of the correct jump is recorded in cm from the line of reflection to the heel of the foot closest to the point of reflection (Sattler et al., 2012). The RSI is derived from the height jumped in a depth jump and the time spent on the ground developing the forces required for that jump [measured by Optojump device (Microgate, Bolzano, Italy)]. The starting position for the depth jump involved the subject standing upright on a 40-cm box. The subjects were instructed to step off from the box and to jump up maximally, attempting to minimize the contact time (Ebben and Petushek, 2010). Three jumping tests were performed, with a rest of 30 s between trials, and the best performance was used as the final achievement for each player.

Kicking-D and Kicking-ND were assessed with the shots taken from the 10-m spots that are used in futsal for accumulation penalty shots (Méndez et al., 2019). A Stalker-type hyper frequency radar instrument, with ±0.16 km/h margin of error (Stalker Professional Radar, Radar Sales, Plymouth, MA, United States) was placed 30 cm above the ground behind a goal. The reliability of this method for measuring kicking speed was previously confirmed (Sedano Campo et al., 2009). Participants needed to shoot standard-size futsal balls with both legs and were allowed to repeat attempts if the shot missed the radar. Five trials were performed, for each leg with a rest of 30–60 s, and the best performance was used as the final achievement for each player.

Sprint was measured with the Powertimer Newtest system (Oulu, Finland). The 5 m sprint and 10 m sprint were conducted together as the 5 m sprint result was a split time for the 10 m sprint. Three timing gates were used: the first was placed on the starting position, the second was placed on the 5-m mark, and the third was placed on the finish line (10 m). In the test, the participant is located in the high position to start, 1 m behind the start line, and starts the test arbitrarily. After the participant crosses the first gate, the time starts. The split time is noted after passing the second gate, and the time stops after the participant passes the third gate (Sekulic et al., 2013). Players performed the test over three trials with a rest of 2 min. The best (minimal) result was observed as the final achievement.

The 20-yard test was used as a measure of generic CODS. This procedure measures the ability of the participant to accelerate and quickly change direction at 180° (Sekulic et al., 2014). The test is organized with three cones placed on the same line with 5 yards between them. The timing gate is positioned at the middle cone, and the starting position of the participants is 0.5 m to the right in a lateral stance. The test starts when participants rotate their bodies to the left and trigger the time while passing the timing gate. The task is to run as quickly as possible to the cone on the left side, change direction and run to the opposite cone 10 yards away. After reaching that cone, the player changes directions again and runs toward the middle cone, stopping the time by passing the timing gate. Measurements were performed with a Powertimer Newtest system (Oulu, Finland), the test was conducted over three trials with 60 s of rest between trials, and the best performance was used in statistical analyses.

The futsal-specific CODS and RAG (FCODS and FRAG) were tested by the recently developed and presented futsal-specific CODS and RAG tests. The performance during FCODS and FRAG followed two procedures: (i) The participants had to touch the ball at the precise moment a change-of-direction occurred (FCODS_T and FRAG_T, respectively) and (ii) the participants dribbled a ball during the execution of each test (FCODS_D and FRAG_D, respectively). All tests had a Y-shaped pattern with the distances specified in **Figure 1** (**Figure 1A** for tests that involved dribbling; **Figure 1B** for tests that involved ball touching). The timing for the FRAG tests began when the participants crossed the initial infrared signal. At that moment, a hardware module lit one 30 cm high cones (A or B). As no prior indication was provided for the FRAG tests, the participants had to quickly notice the specific light and react accordingly. Thus, the FRAG_D and FRAG_T performances were non-planned. For the FCODS tests, the participants had advanced knowledge on which cone would light up and therefore were able to preplan the movement template (Sekulic et al., 2019). Following the suggestions from previous studies, players were familiarized with the FCODS and FRAG tests over two practice sessions held 4–6 days before testing (Pojskic et al., 2018). In brief, all players were required to perform several trials and to demonstrate specific technique proficiency. The players were instructed to perform maximally concentrated tests and to identify the best individual movement strategies. Futsal-specific tests were later tested over five trials, with 1 min rest between trials, in a random order.

For the FRAG_D and FCODS_D, the participants were instructed to dribble a ball (**Figure 1A**) to a marked circle on the ground in front of the designated cone. The participants left the ball within the circle and changed direction to run back to the starting line as quickly as possible. For the FCODS_T and FRAG_T, the participants had to run to the ball, which was placed in front of the cone, touch it with the sole of the foot and run back through the infrared signal to stop the timer (**Figure 1B**). The FCODS_D and FCODS_T were performed over five trials consisting of three attempts. The FCODS was performed over four trials consisting of three attempts (A-B-A, B-A-B, A-B-A, and B-A-B), and players were informed of the upcoming scenario before each trial. The FRAG-D and FRAG_T were performed over five trials consisting of three attempts. Despite the fact that players performed FRAG_D and FRAG_T while not knowing the testing scenario in advance, all players were tested by same testing scenarios but in random order (A-A-B, B-A-B, A-B-A, B-B-A). The FCODS and FRAG tests used in this study were recently studied for reliability and validity, and the results were presented in detail elsewhere (Sekulic et al., 2019).

Measurement of the FRAG and FCODS tests was performed by a hardware device based on an ATMEL microcontroller (model AT89C51RE2; ATMEL Corp, San Jose, CA, United States). A photoelectric infrared sensor (E18-D80NK) served as an external time triggering input, and light emitting diodes were used as outputs. The photoelectric infrared sensor (**Figure 1**) has a response time of less than 2 ms and a digital output signal. The sensor distance for detection ranged from 3 to 80 cm with the ability to detect transparent objects. The sensor was connected with a microcontroller IO port (**Figure 1**). The device was connected to a PC operated on a Windows 7 operating system, as previously presented (Pehar et al., 2018; Pojskic et al., 2018).

Statistics

Variables were checked for normality of the distributions by the Kolmogorov–Smirnov test, and descriptive statistics included means and standard deviations. The test-retest reliability of the variables was previously studied and reported in detail (please see previous text for references), and therefore, in this study, all tests were checked for intratesting reliability by calculation of the intraclass coefficient (ICC), and coefficients of variation (CV).

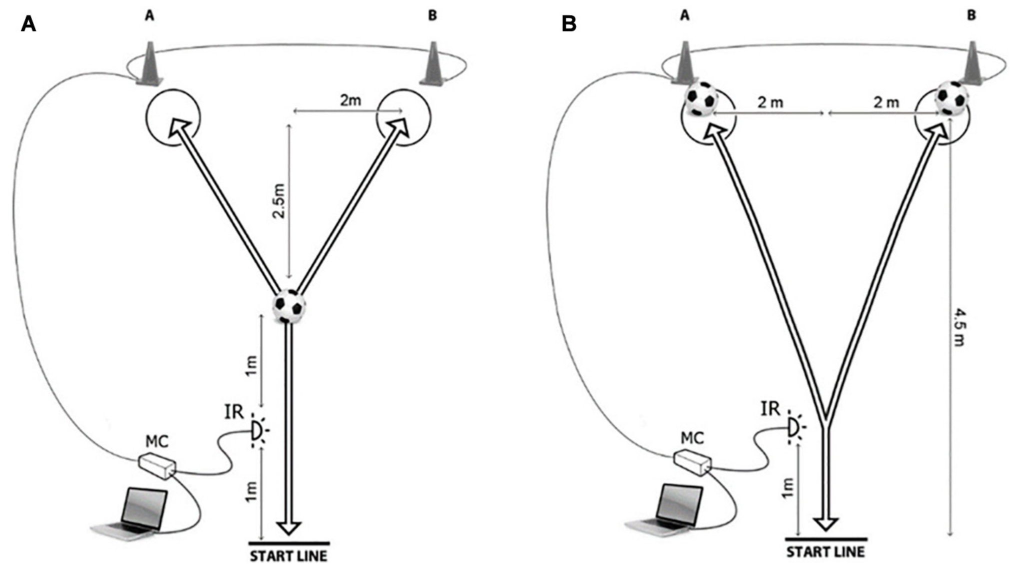

FIGURE 1 | Testing of the futsal specific agility and change of direction speed with dribbling the ball **(A)** and without dribbling the ball **(B)**.

To define the differences between the groups, Student's *t*-test for independent samples was applied and further analyzed using the magnitude-based Cohen's effect size (ES) statistic with modified qualitative descriptors using the following criteria: <0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large; and >2.0 very large differences (Hopkins, 2000).

Multivariate differences between performance-groups (starters vs. non-starters, high-level vs. top-level players) were analyzed by discriminant canonical analysis (DISCRA; forward stepwise model) and percentage of correctly classified cases was reported.

To identify the associations between variables, Pearson's product moment correlation coefficients were calculated. The type I error rate of 5% ($p < 0.05$) was set *a priori* and was considered statistically significant. Stat Soft Statistica ver. 13.0 (Tulsa, OK, United States) was used for all analyses.

RESULTS

Table 1 presents descriptive statistics for all variable in total sample, and intra-testing reliability parameters for physiological tests. In general, all tests had appropriate intra-testing reliability with largest CV (i.e., lowest reliability) for RSI (11%), and FCODS and FRAG tests (8–10%).

Differences derived by *t*-test for independent sample between starters and non-starters are presented in **Table 2**. The ES differences between these performance levels are evidenced in **Figure 2**. In short, starters were significantly taller (small ES), achieved superior results than non-starters in RSI moderate ES), and in Kicking D (moderate ES).

Multivariate differences calculated by DISCRA evidenced RSI and Kicking D as the strongest discriminators of the starters and non-starters, with 75% (n = 30) of non-starters, and 63% (n = 13) of starters being correctly classified (**Table 3**).

Top-level players outperformer high-level players in RSI (moderate ES), SBJ (moderate ES), Kicking D (moderate ES), and FRAG_D (moderate ES) (**Table 4** and **Figure 3**).

TABLE 1 | Descriptive statistics (mean, SD – standard deviation) and reliability parameters (ICC, intraclass coefficient; CV, coefficient of variation) for studied variables.

	Mean	SD	CV	ICC
Height (cm)	182.42	6.03		
Mass (kg)	80.88	11.57		
BMI (kg/m^2)	24.25	2.75		
Body fat (%)	9.14	3.69		
CMJ (cm)	38.61	5.11	0.06	0.80
RSI (index)	145.97	37.45	0.11	0.75
SBJ (cm)	238.89	20.26	0.08	0.88
Kicking D (km/h)	105.39	6.09	0.09	0.79
Kicking ND (km/h)	92.85	9.30	0.10	0.80
Sprint 5 m (s)	0.98	0.09	0.07	0.91
Sprint 10 m (s)	1.71	0.11	0.05	0.93
20 yards (s)	4.65	0.26	0.06	0.90
FCODS_T (s)	2.11	0.19	0.09	0.79
FCODS_D (s)	2.50	0.26	0.08	0.78
FRAG_T (s)	2.42	0.24	0.09	0.77
FRAG_D (s)	2.63	0.25	0.10	0.77

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball.

TABLE 2 | Univariate differences between starters and non-starters in studied variables (*t*-test for independent samples).

	Starters (n = 35)		Non-starters (n = 40)		*t*-Test	
	Mean	SD	Mean	SD	*t*-Value	*p*
Height (cm)	183.89	6.62	181.14	5.21	2.01	0.05
Mass (kg)	82.19	13.73	79.74	9.31	0.91	0.36
BMI (kg/m^2)	24.21	3.00	24.29	2.56	−0.13	0.90
Body fat (%)	8.85	3.74	9.41	3.63	−0.66	0.51
CMJ (cm)	38.73	5.32	38.50	4.98	0.19	0.85
RSI (index)	159.25	37.86	134.35	33.39	3.03	0.001
SBJ (cm)	243.63	19.69	234.75	20.07	1.93	0.06
Kicking D (km/h)	107.01	6.46	103.98	5.44	2.20	0.03
Kicking ND (km/h)	94.66	9.96	91.28	8.50	1.59	0.12
Sprint 5 m (s)	0.98	0.10	0.98	0.08	−0.19	0.85
Sprint 10 m (s)	1.72	0.12	1.70	0.11	0.46	0.64
20 yards (s)	4.62	0.24	4.67	0.28	−0.96	0.34
FCODS_T (s)	2.09	0.17	2.13	0.21	−0.88	0.38
FCODS_D (s)	2.46	0.21	2.53	0.29	−1.06	0.29
FRAG_T (s)	2.40	0.23	2.43	0.25	−0.51	0.61
FRAG_D (s)	2.60	0.22	2.65	0.27	−0.73	0.47

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball.

DISCRA successfully discriminated top-level from high-level players, with 94% of high-level players (n = 55), and 41% of top-level players correctly classified. The most significant discriminators were Kicking D, RSI, BJ, and FRAG_D (**Table 5**).

Apart from logical and expected correlations between anthropometric indices, and various tests explaining the same capacity (i.e., correlations between sprinting variables, correlations between futsal specific CODS, and RAG performances), the correlates of tests previously reported to be highly discriminative between performance groups are particularly interesting. Specifically, RSI and FSRAG_D were negatively influenced by body fat (16 and 10% of the common variance, respectively). Also, RSI was positively correlated to Kicking D (10% of the common variance) (**Table 6**).

DISCUSSION

The aim of this study was to determine the fitness status of professional futsal players and to define the factors that contribute to distinguishing performance levels. The main findings of the study are that (i) top-level players had a higher RSI, better results on the RAG test with a ball, and higher values of maximal kicking speed than high-level players and (ii) starters were taller and had a higher RSI and higher values of maximal kicking speed compared to the non-starters. Therefore, our initial study hypothesis can be partially accepted.

Descriptions

The results of this study are in line with the results of a recent study revealing that futsal players from southeastern Europe are approximately 7 cm taller and 9 kg heavier than players from Italy, Spain, Brazil, and Australia who compete at a similar level of competition (Sekulic et al., 2020). Therefore, we may support conclusions and explanations of investigations in which similar results were evidenced for other sports. In brief, people from southeastern Europe – the former Yugoslav territory (including Croatia, Bosnia and Herzegovina) – are among the tallest European nations, and sport studies evidenced that these countries generally prefer taller athletes in the selection of team-sport athletes (Kondrič et al., 2012).

To efficiently perform specific high-intensity futsal movements (e.g., sprints, jumps, changes of direction), the ability of the lower body to exert force at high speeds (i.e., power output) is essential. In general, this quality is indirectly assessed by different jump and sprint performance tests with the CMJ and 5–20 m dash as the most frequently used tests (Naser and Ali, 2016). The results of this study indicated that players from this study had CMJ performance similar to that of futsal players from the first Brazilian league (38.7 and 39.2 cm, respectively) (Nakamura et al., 2016). Our futsal players performed similarly in 5 and 10 m sprint tests (0.98 and 1.7 s, respectively) to Brazilian futsal players (0.99 and 1.69 s, respectively) (Nakamura et al., 2016).

Shooting performance is one of the most important skills in futsal with speed and accuracy of the ball as the most important factors that affect shooting efficiency (Vieira et al., 2016). Shooting speeds of 108.8 km/h (top-level players) and 104.3 km/h (high-level players) reported in this work for Croatian and Bosnian-Herzegovinian futsal players were similar to those previously reported for Brazilian professionals, including members of the national team (99.7–109.1 km/h) (Milioni et al., 2016; Vieira et al., 2016). Given that the Brazilian national team is the third best in the world (according to the official FIFA rankings), we can say that players from the current study belong to the top tier of world futsal in terms of maximal kicking speed, sprinting, and CMJ performance.

Differences Between Performance Levels

Top-level players had better reactive strength, as expressed by a higher RSI, than high-level players. Given that reactive strength is exhibited in movements consisting of a rapid eccentric contraction followed by a concentric muscle action, we can say that it is crucial in high-intensity activities that utilize the stretch-shortening cycle, such as sprinting, jumping, changing of direction speed, acceleration, and deceleration (Flanagan et al., 2008; Zatsiorsky et al., 2020). In support, our results indicated that players with higher RSIs (i.e., top-level players) performed better on the long jump test than players with lower RSIs (i.e., high-level players). Accordingly, RSI has been shown to have a strong relationship with CODS and acceleration ability in field sport players (Young et al., 2015). In other words, players with higher RSI are able to perform futsal-specific rapid motor actions

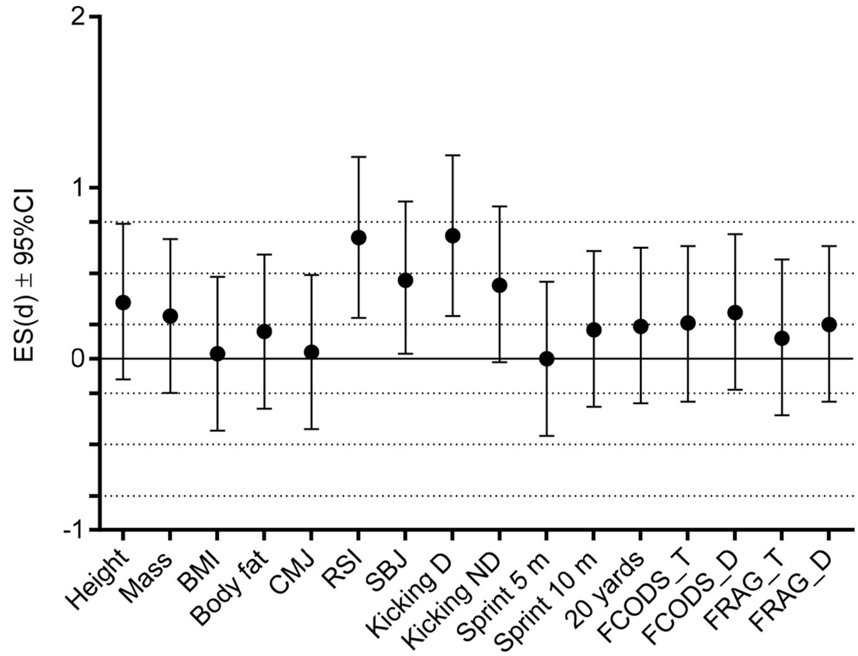

FIGURE 2 | Effect size differences between starters and non-starters in studied anthropometric and physiological variables. CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball. Dashed lines present ES ranges (<0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large differences).

more efficiently. Consequently, this ability may contribute to the success of the entire team by creating performance advantages over the opposing players during futsal matches. For instance, quicker players are more likely to outperform their opponents in situations in which they need to cover and defend certain space on the court or get to the ball first in trying to intercept the opponent's pass (i.e., ball recovery) or receive it from a teammate in an open free space to create a scoring situation. Supportively, very recent study evidenced decelerations (one of the observed game workload variables) as a predictor of players' physical profile (Ribeiro et al., 2020). Knowing that the ability to decelerate is directly related to eccentric muscular properties (similar to RSI), the importance of RSI in defining performance levels is additionally confirmed. It is well known that a higher level of reactive strength contributes to better agility performance (Alvarez et al., 2009). Therefore, it is not surprising that in addition to having better RSIs, top-level players outperformed high-level players in the FRAG_D. However, it is important to note that the FRAG_D applied in this study was quite complex and involved dribbling the ball. Thus, the FRAG_D results were not only affected by agility but also by futsal-specific skills. Such test characteristics emphasize the importance of futsal-specific motor proficiency in identifying performance levels in this sport and directly support the conclusions provided recently in a study in which the reliability and validity of the FRAG_D was explored in a sample of Croatian futsal players (Sekulic et al., 2019). Also, it has already been demonstrated that better players have greater skill in executing such actions than less skillful players (Farrow and Abernethy, 2003).

TABLE 3 | Multivariate differences between starters and non-starters in studied variables (forward stepwise discriminant canonical analysis).

	Canonical root
Height	−0.41
CMJ	−0.04
RSI	−0.62
SBJ	−0.39
Kicking D	−0.45
Sprint 10 m	−0.09
Centroid: non-starters	0.53
Centroid: starters	−0.60
Wilks lambda	0.75
Canonical R	0.49
p	0.01

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg.

Top-level players achieved better results in maximal kicking speed than high-level players. The importance of this capacity was already discussed, and performance-level differences actually confirm the consideration of kicking speed as an important parameter of success in futsal (Ramos-Campo et al., 2016). Interestingly, although kicking speed can be affected by the power of the lower limbs and core, which corresponds to the maximal speed strength produced by the knee extensors, we did

TABLE 4 | Univariate differences between top-level players and high-level players in studied variables (*t*-test for independent samples).

	Top-level (*n* = 17)		High-level (*n* = 58)		*t*-Test	
	Mean	**SD**	**Mean**	**SD**	***t*-value**	***p***
Height (cm)	183.84	7.88	182.01	5.38	1.11	0.27
Mass (kg)	82.44	9.88	80.43	12.06	0.63	0.53
BMI (kg/m^2)	24.33	2.00	24.23	2.95	0.13	0.90
Body fat (%)	8.81	3.01	9.25	3.86	−0.43	0.67
CMJ (cm)	38.86	5.34	38.53	5.08	0.23	0.82
RSI (index)	163.42	38.04	140.86	36.02	2.24	0.03
SBJ (cm)	248.94	17.77	235.95	20.13	2.40	0.02
Kicking D (km/h)	108.82	6.21	104.38	5.72	2.76	0.01
Kicking ND (km/h)	96.41	9.59	91.81	9.03	1.82	0.07
Sprint 5 m (s)	0.98	0.09	0.98	0.09	0.11	0.91
Sprint 10 m (s)	1.71	0.12	1.71	0.11	−0.15	0.88
20 yards (s)	4.59	0.25	4.66	0.26	−1.10	0.27
FCODS_T (s)	2.07	0.15	2.13	0.20	−1.14	0.26
FCODS_D (s)	2.50	0.19	2.50	0.27	−0.01	0.99
FRAG_T (s)	2.35	0.19	2.44	0.25	−1.35	0.18
FRAG_D (s)	2.52	0.22	2.66	0.25	−2.07	0.04

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball.

not find differences between top- and high-level players in CMJ (Bosco, 1999; Rodríguez-Lorenzo et al., 2016). Such a relative discrepancy (e.g., significant performance-level differences in kicking speed without significant differences in CMJ) can be explained by the weak correlation of vertical jump tests (i.e., CMJ) with maximal kicking speed (Rodríguez-Lorenzo et al., 2016), and several potential reasons exist for this result. Finally, the lack of association between CMJ and performance-levels in our study support even the recent considerations of Jiménez-Reyes et al. (2019) regarding the limited applicability of jumping tests in differentiation of the performance-levels in male futsal. First, CMJ is classified as slowing the stretch-shortening cycle (SSC) activity involving slow eccentric-concentric transition compared to the RSI, which is used to evaluate DJ performance as a fast SSC motor task (Ebben and Petushek, 2010). Therefore, it is logical to assume a weak correlation between CMJ as a low SSC activity and kicking performance as a rapid SSC activity. Second, although both activities require the SSC, the same muscles are not involved. In other words, CMJ involves the knee extensors and plantar flexors (e.g., quadriceps and gastrocnemius) as the prime agonist muscles, whereas kicking performance relies on both rapid pre stretching activity of the main hip flexors (e.g., the iliopsoas muscles) and the quadriceps muscles as the prime knee flexors and assisting hip flexors (Kellis and Katis, 2007). Finally, we might anticipate that the kicking technique (i.e., futsal-specific skill) that relies on the rapid SSC is a more important determinant of maximal kicking speed in professional players than the slow SSC activity *per se* evaluated by the CMJ performance. Because of the evident importance of kicking speed in futsal, this issue is additionally discussed later when we evaluate the correlates of kicking speed.

The results of our study did not indicate differences in anthropometrics and body composition indices between top-level and high-level players. In addition, no differences were found in generic CODS test (20 yards), and speed (sprint 5 m, sprint 10 m). The lack of differences between performance level groups in linear sprinting is not surprising. Interestingly, Sheppard et al. (2006) reported that a lower performance group of Australian football players outperformed the higher performance group in a 10 m straight sprint test but showed poorer performance in CODS and RAG tests (Sheppard et al., 2006). Similarly, recent studies suggested that performance level in futsal and football players cannot be differentiated by linear sprinting tests but only by futsal- and football-specific agility tests that include ball handling technique (Pojskic et al., 2018; Sekulic et al., 2019). This observation can be explained by the adopted sports-specific movement (i.e., running, acceleration, and deceleration) technique that includes lowering of the center of gravity, shorter strides, a sideways leaning posture toward the intended direction, and proper foot placement (Haugen et al., 2014). All of these factors together allow the lower-body muscles to apply sufficient and optimal lateral force to the ground, which in turn enables players to maintain balance and efficiently perform futsal-specific tasks that include many rapid changes of direction both with and without the ball (Haugen et al., 2014; Caetano et al., 2015; Santos et al., 2020). These observations together indicate that differences between the studied performance-levels are more closely related to (i) specific futsal skills and (ii) reactive strength, which enables players to efficiently execute futsal-specific movements, as already suggested (Sekulic et al., 2019).

In the present study, differences between starters and non-starters were fewer than between top-level and high-level players. These results may seem surprising because differentiation in these groups was regularly found to be highly discriminative in other team sports (Young et al., 2005; Gabbett et al., 2009). However, it should be emphasized that the decision on the starting line-up in futsal often depends on many different factors that can be highly complex (e.g., tactics, opposing team, game plan, importance of the match) and not directly related to conditioning capacities and futsal-specific skills. Therefore, relatively small differences between starters and non-starters should be contextualized by considering such specifics of futsal tactics. Regardless of all said, the better performance of starters in RSI and maximal kicking speed highlighted the previously discussed importance of these performances in futsal.

As such, the recent findings by Portuguese and Spanish authors (Santos et al., 2020) who investigated key performance indicators that discriminated all-star from non-all-star players during the Euro Cup 2018 Futsal (Slovenia) confirm the relevance of differentiating physical capacities (i.e., kicking speed, futsal-specific agility, and reactive strength) between starters and non-starters in this study. In brief, those authors found that all-star players had greater numbers for key pass accuracy and assists

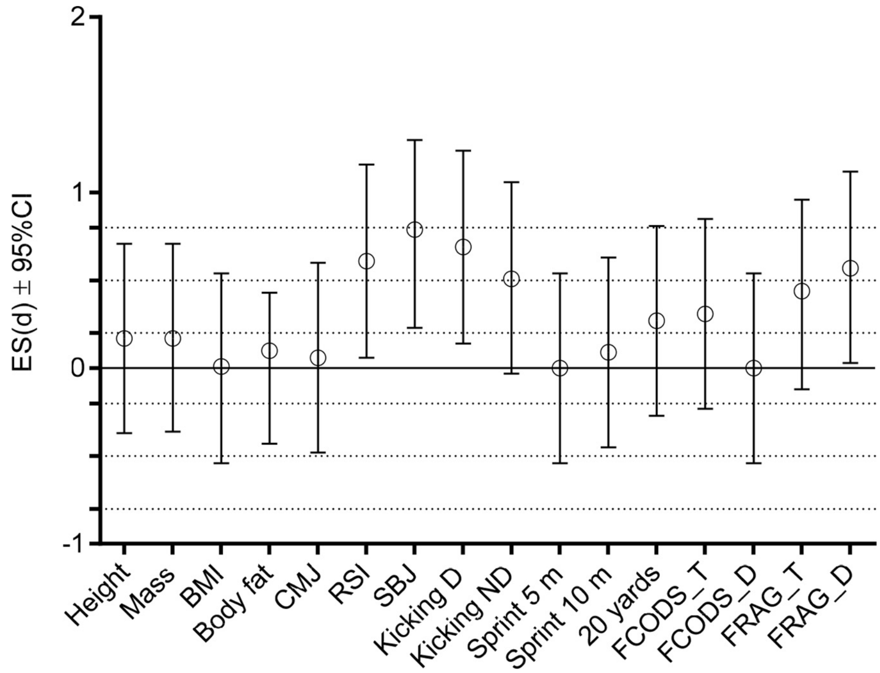

FIGURE 3 | Effect size differences between top-level players and high-level players in studied anthropometric and physiological variables. CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball. Dashed lines present ES ranges (<0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large differences).

and achieved a higher number of goals with a better rate of shots on target during the matches. Moreover, the all-star group was shown to be better in defensive tasks (e.g., ball recoveries and challenges won). To outperform their opponents, futsal players must have not only excellent ball handling technique and anaerobic and aerobic endurance but also a high level of explosive power (e.g., kicking and running speed) and agility capacity. These capacities are especially crucial in defense to offense transitions when ball recovery requires both skillful players who understand the game and players who can predict the opponents' action and can rapidly react by executing sprinting at the right moment and in the right direction, which in turn can enable ball recovery and create a scoring situation (Correa et al., 2014; Santos et al., 2020).

TABLE 5 | Multivariate differences between top-level players and high-level players in studied variables (forward stepwise discriminant canonical analysis).

	Canonical root
CMJ	−0.04
RSI	−0.42
SBJ	−0.45
Kicking D	−0.51
Sprint 10 m	0.03
FCODS_D	0.00
FRAG_D	0.39
Centroid: top-level	0.53
Centroid: high-level	−0.60
Wilks lambda	0.71
Canonical R	0.53
p	0.001

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_D, futsal specific reactive agility test with dribbling the ball.

Correlates of Performances

The results confirmed the importance of RSI, maximal kicking speed and futsal-specific agility performances in differentiation of performance levels in futsal. Although these features are highly complex (i.e., FRAG_D), partially genetically determined (i.e., RSI) and dependent on futsal-specific skills (i.e., kicking speed), the correlates of these physical capacities are important to discuss.

This study evidenced a negative correlation between body fat percentage and RSI and specific futsal agility tests. In other words, players with a higher body fat percentage had poorer reactive strength (i.e., lower RSI) and poorer futsal-specific agility. This conclusion can be elucidated by the "stop and go" nature of the test that permanently required players to change direction speed while overcoming their body inertia, which was more demanding if players had more fat as a non-functional ballast mass (Nikolaidis et al., 2015; Spiteri et al., 2015; Pojskic and Eslami, 2018). To be specific, following Newton's second law, for a constant force, acceleration equals force per mass

TABLE 6 | Pearson's correlation coefficients between studied variables.

	Height	Mass	BMI	Body fat	CMJ	RSI	SBJ	Kicking D	Kicking ND	Sprint 5 m	Sprint 10 m	20 yards	FCODS _T	FCODS _D	FRAG _T
Mass	0.58***														
BMI	0.13	0.88***													
Body fat	0.22	0.77***	0.81***												
CMJ	−0.14	−0.26*	−0.25*	−0.29*											
RSI	−0.12	−0.21	−0.18	−0.42***	0.36**										
SBJ	0.05	−0.20	−0.28*	−0.46***	0.63***	0.37**									
Kicking D	0.27*	0.12	−0.02	−0.16	0.25	0.35**	0.33**								
Kicking ND	0.28*	0.07	−0.09	−0.14	0.12	0.14	0.37**	0.61***							
Sprint 5 m	0.08	0.38***	0.42***	0.46***	−0.26*	−0.24*	−0.28*	−0.24*	−0.10						
Sprint 10 m	0.14	0.33**	0.32**	0.38**	−0.40***	−0.25*	−0.42***	−0.34**	−0.21	0.77***					
20 yards	0.05	0.46***	0.54***	0.63***	−0.39***	−0.46***	−0.46***	−0.30**	−0.40***	0.37**	0.40***				
FCODS_T	0.14	0.29**	0.25*	0.33**	−0.21	−0.31	−0.24*	0.05	0.09	0.06	0.09	0.43***			
FCODS_D	0.16	0.40***	0.38***	0.33**	−0.21	−0.21	−0.26*	−0.07	−0.08	0.16	0.13	0.51***	0.61***		
FRAG_T	0.06	0.27	0.26*	0.34**	−0.22	−0.22	−0.28*	−0.02	0.00	0.06	0.12	0.42***	0.66***	0.59***	
FRAG_D	−0.02	0.20	0.24*	0.35**	−0.12	−0.21	−0.22	−0.06	−0.07	0.09	0.11	0.40***	0.61***	0.63***	0.70***

CMJ, countermovement jump; RSI, reactive strength index; SBJ, standing broad jump; Kicking D, kicking speed dominant leg; Kicking ND, kicking speed non-dominant leg; 20 yards, generic change of direction speed test over 20 yard distance; FCODS_T, futsal specific change of direction speed test without dribbling; FCODS_D, futsal specific change of direction speed test with dribbling the ball; FRAG_T, futsal specific reactive agility test without dribbling; FRAG_D, futsal specific reactive agility test with dribbling the ball.
$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

(e.g., a = F/m), which means that by reducing body mass (i.e., fat mass reduction), players could be able to accelerate their bodies at higher rate, and in turn, with higher body fat, mass acceleration could be slower. In other words, reducing the body fat mass of players could improve relative strength, which could inherently enable them to move more efficiently (e.g., accelerate and decelerate at higher rate) and perform futsal-specific tasks at superior level.

However, it is very important to emphasize that reducing body fat in futsal players could have multiple positive effects. First, excess body weight may be associated with an increased risk of fatigue and injuries (Martinez-Riaza et al., 2017). Therefore, a lower BF% can be observed as protective in injury prevention among futsal players. In addition, reducing body fat could likely have a positive effect on both reactive strength and futsal-specific agility. Specifically, such influence is suggested for other team sports in which jumping capacities and agility are important determinants of success (Sattler et al., 2015; Sisic et al., 2016; Pehar et al., 2018). Consequently, a decrease in body fat could improve the efficiency of execution of futsal-specific movements, ultimately increasing overall futsal performance.

Futsal players who were able to produce a higher maximal kicking speed were more agile. Although an explanation of the causality for this association is not within the scope of this paper, we attempt to indicate a possible background of the association and possible implications of this correlation in kicking performance. In short, throughout the kicking maneuver, the supporting leg (i.e., non-dominant leg) is responsible for the stability of the body during the swing phase and during the foot-ball contact phase (Rodríguez-Lorenzo et al., 2016). Generally, the main function of the supporting leg during shooting on the goal or passing is to absorb and resist the strong external forces to stabilize the body (Inoue et al., 2014). This type of work is characterized by negative force, and the muscles of the supporting leg (in running, this is called the loading phase) predominantly work eccentrically (Rorke, 1995). Consequently, the supporting leg should be well-trained in terms of eccentric strength, which directly influences kicking performance.

In addition, given that both kicking and sprinting performance are dependent on effective eccentric strength of the hip flexors and concentric strength of both the hip and knee extensors, a positive correlation was expected between them. In brief, to perform kicking at high speed (i.e., a quick shank and foot movement forward), it is important that the action is preceded by a rapid prestretch of the hip flexors and the knee extensors (i.e., fast backswing of the leg) (Kellis and Katis, 2007). In the same way, to quickly run, one must rapidly propel the legs forward by explosively lifting alternate legs (i.e., the thigh) off the ground and placing them forward. The optimal stride length, frequency and speed require rapid backswing of the leg that in turn results in prestretch of the hip flexors and the knee extensors. Therefore, both activities involve utilization of the SSC that enables augmented concentric (i.e., propulsive) muscular contraction of the legs. This action is possible because of ability of the musculotendinous system to store elastic energy when rapidly stretched (i.e., during eccentric muscular contraction) and to release it during propulsive movements (i.e., concentric muscular contraction) (Zatsiorsky et al., 2020). Additionally, rapid muscular lengthening is detected by the muscle spindles that induce the stretch reflex, which inherently increases the contraction strength of the agonist muscles during the concentric phase (e.g., take-off in running or jumping) (Zatsiorsky et al., 2020).

Similarly, it is well known that higher eccentric strength of the legs can contribute to better execution when performing change of directions (i.e., because it helps to efficiently decelerate the body, which allows faster performance of change of direction) (Brughelli et al., 2008; Kovacs et al., 2008; Jones et al., 2009; Spiteri et al., 2014; Chaabene et al., 2018). In addition, the supporting leg permits more reactive strength and better motor control of push-off actions, which allows faster 180° turns to be performed (Zouhal et al., 2018). Given that changes of direction at 180° are characteristic for the agility tests used in this work, it even explains the correlation between kicking speed and agility in our study. However, all previous discussions should be contextualized in light of a correlation between RSI and kicking speed and agility performance (i.e., RSI is significantly correlated with both performances). In brief, both kicking speed and agility performance are generally influenced by RSI (eccentric properties), and the association between agility and kicking speed should be at least partially observed as a result of statistical suppressor effect.

Limitations and Strengths

The most important limitation of the study comes from its cross-sectional design. Therefore, although some causalities may be intuitively interpreted (body fat is almost certainly a cause of impaired performance and not vice versa), further studies are needed to evaluate the clear cause-and-effect among variables. Additionally, this study focused on motor performance, and indicators of aerobic and anaerobic endurance were not observed. Finally, although all teams were tested on the same floor (a standard wooden pitch where teams play official games), the measurement was not absolutely standardized.

This is one of the rare studies in which a relatively large sample of professional players were studied on a set of generic and futsal-specific physiological and anthropometric variables. All players were tested in a relatively short time span (e.g., in 3 weeks), which limited the possibility that seasonal variations significantly influenced the achievements. Finally, this is one study in which an international sample was observed and in which the pursuit of excellence was evaluated. Therefore, we believe that although it is not the final word on the topic, this study can contribute to knowledge in the field and promote initiation of further research.

CONCLUSION

In conclusion, our findings suggest that reactive strength, kicking speed and futsal-specific RAG are important determinant of success (performance-level) in futsal. Knowing the level of the studied players (e.g., professional players of the highest national/international rank) we can conclude that these capacities can be considered essential qualities required for advanced performance in futsal. Collectively, findings of the study allow us to draw some conclusions which will hopefully improve even the training and conditioning in futsal.

Specifically, strength and conditioning coaches should focus on improving player ability to rapidly transit from eccentric to concentric muscular contractions emphasizing short ground contact time when performing different motor tasks (e.g., change of direction, sprinting, jumping). For this purpose, training programs that emphasize development of reactive strength of the leg extensors (e.g., plyometric training) would be particularly useful. Namely, application of such program will improve different conditioning capacities we have evidenced as being important determinants of success (i.e., reactive strength, kicking speed), and will consequently improve the qualities correlated to trained capacities (i.e., agility components).

Training programs in professional level futsal should include drills aimed on improvement of futsal-specific conditioning capacities, such as futsal specific RAG. Additionally, futsal strength and conditioning training should be targeted toward including futsal-specific skills (e.g., dribbling, shooting) in RAG drills. In development and application of such training, we may suggest progressive approach. Specifically, program should start with generic closed-skill drills and gradually progress to open-skill drills in which players are required to respond to various simple stimuli (e.g., a signal provided by a coach). Subsequently, exercises should include futsal-specific and decision-making "read and react" drills with real opponent(s) and match-like situations (e.g., "ball recovery drills," "one-on-one play," "small-sided games," etc.).

Futsal training should focus on development of the eccentric strength of the hip flexors and knee extensors, which could improve the ability of the lower limbs to rapidly generate muscular force. This ability could provide players not only with the ability to accelerate and decelerate quickly in different movement directions but also to improve kicking speed, which is associated with a higher angular velocity of the knee joint and a faster approach of the player to the ball.

Special attention should be focused on proper learning of a CODS technique that includes lowering of the center of gravity, shorter strides, and proper foot placement. This improvement could enable players to move efficiently and to decelerate and stabilize the support leg, thus enabling greater muscle forces to be exerted when attempting to kick the ball.

Advanced lower-body strength relative to athlete body mass could be crucial in futsal play when players are continuously required to accelerate and decelerate while overcoming their body inertia. Supportively, our results indicated negative association between body fat percentage and several important futsal specific conditioning capacities. Therefore, professionals working with futsal players are encouraged to pay attention on body composition of their players. For such purpose (i.e., reduction of the body fat indices), specific nutritional regimes should be prioritized over extensive aerobic training (because of its potentially negative effects on power and sprinting capacities).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the University of Split, Faculty of Kinesiology (Ethical Board Approval No: 2181-205-02-05-14-001). Written informed consent to participate in this study was provided by the participants.

AUTHOR CONTRIBUTIONS

DS conceived and designed the study. IZ, MP, TM, and SV collected the data, performed the statistical analyses, and participated in drafting the manuscript. DS, TM, SV, and DN undertook the data analysis and interpretation. DS, HP, IZ, and MP gave an overview of the previous research and discussed the data. DS and HP did critical revision of the manuscript. All authors substantially participated in final manuscript versions, approved the submitted version, and agreed to be accountable for all aspects of the work.

FUNDING

Support of the Croatian Science Foundation (IP-2018-01-8330 and DOK-2020-01-9298) is gratefully acknowledged.

ACKNOWLEDGMENTS

Special thanks go to all players who voluntarily participated in the study.

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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.

ORIGINAL RESEARCH
published: 22 January 2021
doi: 10.3389/fpsyg.2021.625154

Physical Demands in Elite Futsal Referees During Spanish Futsal Cup

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In futsal there are two referees on the playing court and their capacity to respond to physical and physiological demands imposed during the game is essential for the success. The futsal characteristics such as size pitch, referees position and rules of games or type of league could impose specific physical efforts probably. The aim of this study were to analyze the physical demands of eight elite referees (age 40 ± 3.43 years; height 1.80 ± 0.03 m; weight 72.84 ± 4.01 kg) from seven matches of Spanish Futsal Cup 2020. The physical activity of each referee during the match was monitored with a Local Positioning System, which was installed on futsal pitch where the matches were played. The data differences were evaluated as Paired-Samples *T*-Test procedure. The results revealed a similar total distance between halves (2888.39 vs. 2831.51 m). The zone 3 distance (15.1–18 km·h^{-1}) showed a significative decrease ($p < 0.05$) during the match in comparison to the first and second halves (−24.48 m; CI95%: −9.54 to −39.42; ES: 0.56). The number of high-intensity acceleration (−10.29; CI95%; 3.71–16.86; ES: 0.92) and deceleration (−24.86; CI95%; 11.59–38.12; ES: 0.99) decreased in the second half of the match ($p < 0.05$). Therefore, the use of the tracking device to monitoring physical performance provides knowledge of the specific activity profile from futsal referees. This information to can be useful to design more accurate the training programs.

Keywords: match monitoring, activity profile, indoor tracking system, physical performance, futsal

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *02 November 2020*
Accepted: *04 January 2021*
Published: *22 January 2021*

Citation:
Serrano C, Sánchez-Sánchez J, Felipe JL, Hernando E, Gallardo L and Garcia-Unanue J (2021) Physical Demands in Elite Futsal Referees During Spanish Futsal Cup. Front. Psychol. 12:625154. doi: 10.3389/fpsyg.2021.625154

INTRODUCTION

Team sports have a referee, who has the responsibility of ensuring matches develop according to the regulations. For this reason, they must follow the game with full attention and precision control (Borin et al., 2013). Additionally, the referee's capacity to respond to physical and physiological demands imposed during the game is essential for the success of refereeing in different sports (Reilly and Gregson, 2006; Weston et al., 2007; Bloß et al., 2020; García-Santos et al., 2020). The physical demands of referees have been the subject of studies during the last years in different team sports like Australian football (Elsworthy et al., 2014), rugby (Brightmore et al., 2016), or football (Castagna et al., 2019) due to the development of wearable technology, such as global positioning systems (Chambers et al., 2015; Scott et al., 2016).

Futsal is an indoor team sport with a 2 × 20 min game of high-intensity and intermittent actions (Naser et al., 2017). The specific characteristics of futsal, such as the dimension of pitch, position of the referee, or rules of the game, may lead to different physical and physiological efforts to football, in spite of the similarities of refereeing in these two sports (Rebelo et al., 2011). The recent progress in technology has made it possible to track time and motion analysis and the physical demands of indoor team sports with validity and accuracy in reference to determining distance covered, speed, mean velocity, accelerations, and decelerations for intermittent activities (Bastida Castillo et al., 2017; Vieira et al., 2017; Serpiello et al., 2018; Bastida-Castillo et al., 2019; Gómez-Carmona et al., 2019). Regarding indoor team sports, referees' match performance has been analyzed in futsal with video analysis (Rebelo et al., 2011) and basketball with tracking devices (Borin et al., 2013; García-Santos et al., 2019; Leicht et al., 2019).

In futsal there are two principals referees on the playing court and it is necessary that they maintain a good position regarding the run of play in the game in order to observe possible infractions. In reference to these requirements, Rebelo et al. (2011) showed the activity of futsal referees is generally characterized by intermittent moderate to high intensity running with numerous very brief bouts of fast speed and sprint, interspersed by long periods of low-intensity recovery. Moreover, there are a lot of high neuromuscular actions required due to large demands of backward movements (Ahmed et al., 2017).

In the last few years, the inertial devices with Ultra-Wide Band (UWB) technology by local positioning systems (LPS) have enabled the monitoring of positioning and the obtaining of the performance of elite futsal players, it showed the activity profile during official competition (Illa et al., 2020; Ribeiro et al., 2020; Serrano et al., 2020). Nevertheless, the scientific knowledge regarding the physical and physiological demands of professional referees during competition exist, further evidences are necessary to establish an accurate activity profile. Additionally, there are not previous information of physical demands or movement patterns of elite futsal referees with tracking technology device during official games, it was only with video-analysis systems (Rebelo et al., 2011; Ahmed et al., 2017).

Therefore, the aim of the present manuscript was to analyze the activity profile and to compare the physical demands of elite futsal referees between first and second halves during official matches from Spanish Futsal Cup using Local Positioning System technology for monitoring their movement patterns.

MATERIALS AND METHODS

Participants

A total of eight elite Spanish futsal referees (age 40 ± 3.43 years; height 1.80 ± 0.03 m; weight 72.84 ± 4.01 kg) participated in this study (14 observations, seven matches and two referees per match). The power of the statistical results was 0.9196 for the selected sample. The training program of referees was constituted by five sessions per week. Training sessions were composed of aerobic-anaerobic work and injury prevention exercises. All of them had at least 10 years of experience in the first division of the National Spanish Futsal League (LNFS). They were selected by the National Committee of Referees for participating in the Spanish Futsal Cup 2020.

Design

The referees were monitored during seven games, which were distributed in the quarter-finals, semi-finals and final over 4 days. All of the participants were informed about the study requirements and provided written informed consent. The study protocol was approved and followed the guidelines established by the local Institution – Ethics Committee of the European University of Madrid (CIPI35/2019) – and in accordance with the recommendations of the Declaration of Helsinki.

Methodology

The physical activity of each referee during the match was monitored with an individual WIMU PRO^{TM} device (Realtrack Systems S.L., Almería, Spain) with a frequency of 18 Hz was ubicated in a mini pocket of a special vest located between the shoulder blades. The Local Positioning System (LPS) with Ultra-Wide-Band technology (UWB), which was installed on the futsal pitch where the matches were played, it was activated after warm up of referees with an autocalibration of the antennae of 5 min (Bastida-Castillo et al., 2019). This system is constituted by a set of six antennae (**Figure 1**) that transmit the radiofrequency signal almost under the same principle as the GPS system (Sczyslo et al., 2008). The accuracy and reliability of LPS has been demonstrated in reference to determining distance covered, speed, mean velocity or accelerations for intermittent activities (Stevens et al., 2014; Serpiello et al., 2018). The LPS can calculate the distance or acceleration extracting the means of measuring the changes in the frequency of the periodic signal emitted (Rico-González et al., 2020). Furthermore, the use of device with a 10-Hz sampling frequency, it has been shown that the occurrence of high-intensity accelerations and decelerations can be reliably obtained (Harper et al., 2019). The WIMU PRO^{TM} have showed an accuracy (bias: 0.57–5.85%), test–retest reliability (%TEM: 1.19), and inter-unit reliability (bias: 0.18) in Bastida Castillo et al. (2018) and a large ICC for the x-coordinate (0.65) and a very large

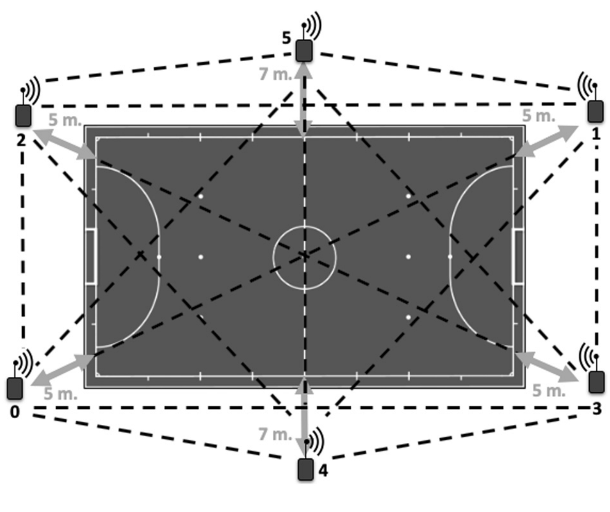

FIGURE 1 | Antennae distribution of Local Positioning System on futsal pitch (Serrano et al., 2020).

ICC for the y-coordinate (0.88), with a good 2%TEM in Bastida-Castillo et al. (2019). The heart rate (HR) was monitored during all games by using a cardiac frequency band (Garmin Ltd., Olathe, KS, United States) synchronized with the inertial device through wireless ANT + technology (García-Santos et al., 2019).

The specific software SPRO^{TM} v. 960 (Realtrack Systems S.L., Almería, Spain) was used to obtain and analyze the referee performance for each match. The physical activity were considered in accordance with previous futsal studies (Ribeiro et al., 2020; Serrano et al., 2020). *The movement pattern variables were*: Total Distance Covered (m); High-Speed Running Distance (HSR: >15.1 km·h^{-1}); High Speed Running Count (n); High Speed Running Percent (%); Distance-covered in speed zones – ZONE 1 (Z1): walking and low-intensity running (0–10 km·h^{-1}), ZONE 2 (Z2): medium-intensity running (10.1–15 km·h^{-1}), ZONE 3 (Z3): high-intensity running (15.1–18 km·h^{-1}), ZONE 4 (Z4): sprinting (>18.1 km·h^{-1}); Sprint Distance (m); Sprint Count (n); Sprint Average Duration (s); Maximal Speed ($Speed_{MAX}$: km·h^{-1}). *The heart rate variables were*: Maximal Heart Rate (HR_{MAX}: bpm); Average Heart Rate (HR_{AVG}: bpm); Relative HR percentage ($HR_{RELATIVE}$:%). *The acceleration and decelerations variables were*: Explosive Distance (distance with ACC > 1.12 m·s^{-2}); Total number (n) and distance (m) of Accelerations (ACC: m·s^{-2}) and Decelerations (DEC: m·s^{-2}); Maximal Acceleration (ACC_{MAX}: m·s^{-2}) and Deceleration (DEC_{MAX}: m·s^{-2}); Number (n) and distance (m) of accelerations and decelerations for high intensity (>3 m·s^{-2}).

Statistical Analysis

Data are presented as means ± standard deviations (SD) along with the 95% confidence interval (95%CI). Before carrying out the analyses Shapiro–Wilk distribution test was performed to confirm a normal distribution of the variables. Differences between first half vs. second half were evaluated through as paired-samples *T*-test procedure. The level of significance was set at $p < 0.05$. The *post hoc* analysis was adjusted using the Bonferroni method. Effect size (ES) was calculated and defined as follows (Cohen, 1992): trivial (ES < 0.19); small (ES = 0.2–0.49); medium (ES = 0.50–0.79) and large (ES > 0.8). All data were statistically analyzed using SPSS V24.0 and G*Power, for Windows.

RESULTS

Movement pattern and heart rate variables are presented in **Table 1**. HSR count (n) showed higher values in first half (+3.07; ES: 0.47) than second half. Additionally, in the second half the $HR_{RELATIVE}$ was significantly lower than the first half of the match (−2.46%; ES: 0.29). The rest of variables presented in **Table 1** did not revealed significant differences ($p > 0.05$).

Figure 2 describes the distance in different ranges of speed covered by referees. No significant differences ($p > 0.05$) were revealed for all ranges of speed, except distance covered in Zone 3 ($p = 0.004$). This range was significantly lower in the second period of the match in comparison with the first period (−24.48 m; ES: 0.56).

The acceleration and deceleration variables are shown in **Table 2**. The referees evidenced a lower explosive distance in the second period compared with the first period (−50.31 m; ES: 0.70). The number of high-intensity acceleration (+10.29; ES: 0.92) and deceleration (+24.86; ES: 0.99) actions revealed significant higher values than those of the second half ($p < 0.05$). Furthermore, distance in ACC and DEC also revealed significant lower results in second half (−40.07 m; ES: 0.63 and −26.81 m; ES: 0.40, respectively) compared to first half.

DISCUSSION

The purpose of this study was to analyze the activity profile and to compare the physical demands of elite futsal referees between first and second halves during official matches from Spanish Futsal Cup. This is the first research to describe the activity profile of professional futsal referees during an official competition with tracking time-motion technology. The main findings were that high intensity running distance and acceleration decrease during second period of the match. Additionally, the low and moderate intensity running distances and the total number of accelerations remain similar in both periods.

Previous studies have investigated the physical performance of futsal referees (Rebelo et al., 2011; Dixon, 2014; Ahmed et al., 2017). The activity profile revealed by these authors showed similar outcomes to those of the present investigation in relation to volume variables (Rago et al., 2020) corresponding to total distance (5719.91 ± 249.66 m). Additionally, the activity profile of referees presented long distances of slow and moderate speeds (5156.42 ± 456.76 m) among with less distances of high-speed running and sprint (557.37 ± 164.30 m). Although the distribution of activities reported comparable values, the results of the distances covered in the different ranges of speed by the referees of the present manuscript were dissimilar to those of previous studies. It may be explained by the different speed categories selected (Rebelo et al., 2011; Ahmed et al., 2017). Nevertheless, the data obtained in present study confirmed the specific motor pattern of elite futsal referees. Regarding these results, the training programs should be adjusted according to specific competitive characteristics (García-Santos et al., 2019).

The analysis of internal load showed that referees had a HR_{AVG} of 146.00 ± 16.1 and they were working around 75% HR_{MAX}. Although, the heart rate could modify due to level of competition or type of referee, similar values to previous investigations due to prior investigations (Rebelo et al., 2011; Dixon, 2014; Ahmed et al., 2017). These outcomes showed that the level of fitness futsal referees must be requirement to tolerate this values. Moreover, the variables of heart rate revealed a reduction in the second half, although without significative differences, it might indicate a tendency to reduce the performance of internal load. This could be influenced by the situational variables of the match (Castillo et al., 2016).

In the comparison of performance between periods of the match, Ahmed et al. (2017) reported a decline in total distance covered by futsal Iraq Futsal Premier League referees (3093 ± 271

TABLE 1 | Movement pattern and heart rate demands of referees during match.

Variables	Full match	First half	Second half	Sig. (*p*)	ES	95% CI	
Movement pattern							
Total distance (m)	5719.92 ± 249.66	2888.40 ± 122.56	2831.52 ± 150.26	0.08	0.41	−8.61	122.37
HSR distance (m)	442.84 ± 108.87	235.06 ± 67.58	207.78 ± 57.86	0.12	0.44	−9.12	63.69
HSR count (n)	45.36 ± 12.16	24.21 ± 6.65	21.14 ± 6.31*	0.02	0.47	0.47	5.66
HSR distance percent (%)	7.71 ± 1.72	8.12 ± 2.19	7.31 ± 1.90	0.19	0.40	−0.48	2.09
Sprint distance (m)	80.09 ± 39.62	41.55 ± 28.64	38.54 ± 17.76	0.67	0.13	−12.28	18.30
Sprints count (n)	9.00 ± 4.66	4.50 ± 3.13	4.50 ± 2.28	1.00	0.00	−1.66	1.66
Sprint AVG duration (s)	1.85 ± 0.23	1.90 ± 0.28	1.80 ± 0.29	0.29	0.34	−0.10	0.29
$Speed_{MAX}$ (km/h)	19.78 ± 0.58	19.74 ± 0.58	19.70 ± 0.56	0.34	0.07	−0.05	0.13
Heart rate							
HR_{MAX} (bpm)	165.77 ± 11.45	164.45 ± 17.43	158.64 ± 12.98	0.13	0.38	−2.04	13.67
HR_{AVG} (bpm)	146.00 ± 16.11	149.36 ± 17.08	142.55 ± 15.92	0.05	0.41	−0.16	13.79
$HR_{RELATIVE}$ (%)	74.68 ± 8.70	74.95 ± 8.68	72.48 ± 8.45*	0.00	0.29	0.77	4.16

**Significant differences between first and second half for a given variable (p < 0.05); CI, confidence interval; ES, effect size; HSR, High Speed Running; AVG, average; HR, Heart Rate; MAX, maximal.*

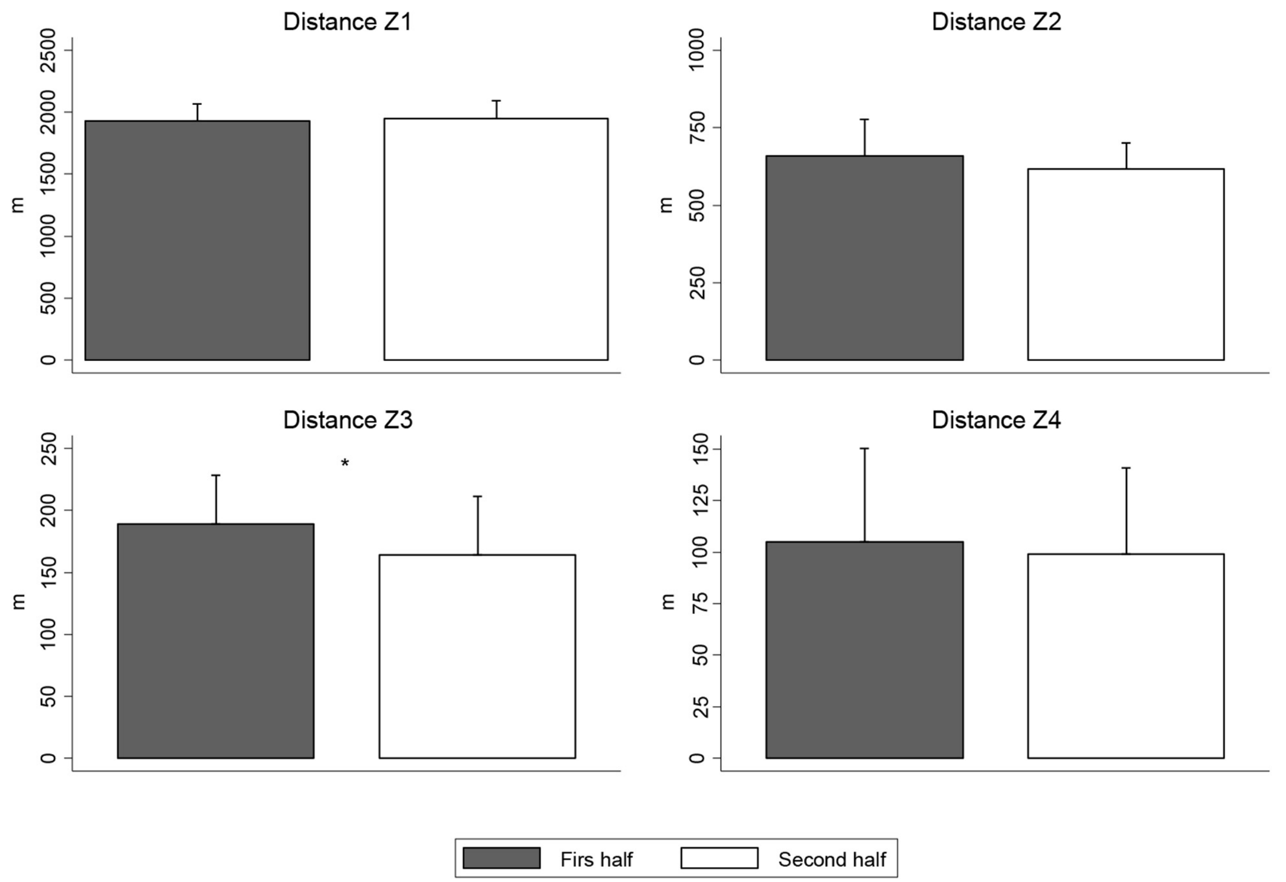

FIGURE 2 | Distance covered in different speed ranges. *Significant differences between first and second half for a given variable ($p < 0.05$). Z1, zone 1 (0–10 km·h^{-1}); Z2, zone 2 (10.1–15 km·h^{-1}); Z3, zone 3 (15.1–18 km·h^{-1}); Z4, zone 4 (>18.1 km·h^{-1}).

vs. 2850 ± 219 m). Contrary to the findings of these studies, the present results showed similar total distances covered in both halves (2888.39 ± 122.55 vs. 2831.51 ± 150.26 m). The movement patterns of referees were monitored by new tracking device in the present study. The difference in the technology or the type of competition studied might explain

TABLE 2 | Acceleration and deceleration demands of referees during match.

Variables	Full match	First half	Second half	Sig. (p)	ES	95% CI	
Explosive distance (m)	922.04 ± 137.31	486.17 ± 80.12	435.86 ± 63.99*	0.00	0.70	23.37	77.25
ACC (n)	954.79 ± 191.30	495.57 ± 102.00	459.21 ± 95.74*	0.02	0.37	7.23	65.49
DEC (n)	2096.29 ± 335.81	1045.43 ± 166.41	1050.86 ± 179.28	0.81	0.03	−53.38	42.52
ACC_{MAX} ($m \cdot s^{-2}$)	4.56 ± 0.39	4.54 ± 0.39	4.50 ± 0.39	0.14	0.10	−0.01	0.09
DEC_{MAX} ($m \cdot s^{-2}$)	−4.10 ± 0.32	−4.09 ± 0.32	−4.08 ± 0.32	0.50	0.03	−0.04	0.02
ACC distance (m)	391.15 ± 114.37	215.61 ± 74.82	175.54 ± 51.82*	0.02	0.63	5.98	74.17
DEC distance (m)	323.51 ± 130.31	175.16 ± 67.78	148.35 ± 66.26*	0.01	0.40	8.66	44.96
ACC > 3 $m \cdot s^{-2}$ (n)	80.86 ± 20.01	45.57 ± 13.90	35.29 ± 8.48*	0.01	0.92	3.71	16.86
DEC > 3 $m \cdot s^{-2}$ (n)	236.14 ± 45.08	130.50 ± 29.41	105.64 ± 20.37*	0.00	0.99	11.59	38.12
ACC > 3 $m \cdot s^{-2}$ (m)	317,8 ± 82.58	171.71 ± 46.53	146.09 ± 44.50*	0.03	0.56	3.48	47.76
DEC > 3 $m \cdot s^{-2}$ (m)	284.72 ± 97.57	153.18 ± 50.24	131.54 ± 49.20*	0.00	0.44	10.57	32.73

**Significant differences between first and second half for a given variable ($p < 0.05$); CI, confidence interval; ES, effect size; ACC, acceleration; DEC, deceleration; MAX, maximal.*

why the results were not similar. There are investigations with analyses of the relative distance covered by elite futsal players during official matches, which demonstrated that they maintain similar values between halves (Serrano et al., 2020) or even experiment an increase (Ribeiro et al., 2020). The development of the game and the different contextual variables that exist during matches could be the reason of these differences (Méndez et al., 2019). This fact could be influenced by the referee having to be near the game, which means they need to cover different distances in each game depending the course of the match.

The results from the distance covered and the number of high-speed runs in the present investigation revealed a significant decrease in the second half compared with the first half. The performance of this variable have showed similar behaviors that others futsal referees studies in the comparison between halves (Rebelo et al., 2011; Ahmed et al., 2017). The specific situations of futsal matches might reduce the rate of the play in the second half affecting the referees' performance in terms of these types of physical demands. Although the goalkeeper-player situations did not contemplate in the present investigation, this tactic situation is preferentially adopted in several futsal games (Méndez-Domínguez et al., 2019) and it could modify the speed of the play and that to influence the referee's activity. The high speed performance of the present results showed lower total distance of high-speed runs (442.84 ± 108.87) than previous investigations (Rebelo et al., 2011; Ahmed et al., 2017). The zones of speed used and the tracking technology might explain the differences distance covered in this manuscript compared to previous studies. Moreover, the type of competition analyzed in the present study was different format than the other studies which were regular competition. The studies with elite futsal players of different leagues have exposed dissimilar physical performances in this type of demands (De Oliveira Bueno et al., 2014; Ribeiro et al., 2020; Serrano et al., 2020) and it could happen in referees too.

With regard to the acceleration and deceleration variables, this study is the first to provide detailed information on these kinds of actions by futsal referees. Previous research have reported different actions, such as stops, turns, or sideways running during games (Rebelo et al., 2011; Ahmed et al., 2017). The results of the present manuscript confirm that this type of demands are an important part of the activity profile of futsal referees due to elevated number of high-intensity accelerations and decelerations. Recent futsal studies have showed that these demands should be considered in profile of player because the ability to accelerate and decelerate have been evidenced during games (Illa et al., 2020; Ribeiro et al., 2020; Serrano et al., 2020). Additionally, the values of high-intensity accelerations and decelerations indicated a decrease of the performance in the second half. Although, the present study did not analyze the performance of players, the development of game and activity of players be able to influence the performance of these demands due to the activity of referees is dictated by the activity of the game (Ahmed et al., 2017). This type of actions require high eccentric force and it might produce an accumulation of muscular fatigue (Edwards, 2018). Therefore, the monitoring of this actions revealed some interesting outcomes which could be helpful in the design of strength and conditioning programs of futsal referees.

LIMITATIONS

One of the limitations this study is the low number of referees and matches assessed. However, this research analyzed the whole Spanish Futsal Cup 2020 and tested the highest-level referees in Spain. Another limitation is the tournament itself as only winners moved to the following round and it could have influence over the performance of matches. Therefore, future studies should analyze longer tournaments like regular league and higher number of referees to confirm our findings. Additionally, the possible correlation between the physical parameters of referees and players' physical demands in competitions could lend support to understanding the physical profile and performance of the referees (Ahmed et al., 2017; García-Santos et al., 2020). Furthermore, the knowledge of this relationship could help to detect the possibility of most demanding scenarios from referees during the competition (Gabbett, 2016; Oliva-Lozano et al., 2020; Vázquez-Guerrero et al., 2020).

CONCLUSION AND PRACTICAL APPLICATIONS

Thus, the findings confirmed that the specific profile activity of elite futsal referees show long distances of slow and moderate speeds with minor high-speed running and sprint distances. Moreover, a great number of high-intensity deceleration actions were proved. In addition, the present study found a decrease in physical performance by the referees in relation to the high-intensity actions when comparing the first and second halves. It could be due to the referees must be follow the players and the specific situations during futsal games. It might reduce the intensity of the match in the second half affecting the referees' performance.

Finally, the use of the tracking device to monitoring physical performance provides knowledge of the specific activity profile from futsal referees. This information to can be useful to design new physical testing and more accurate the training programs. This will help the referees to meet the workload demand during the game and to make accurate decisions without a high level of fatigue. Therefore, the possibility of associating the acceleration and deceleration variables among specific movements of referees may contribute to producing individual training programs to improve this kind of skill and to reduce the injury risk due to these physical demands.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: The raw data supporting the conclusions cannot be made available due to the restrictions defined by the Spanish National Committee of Referees. Requests to access these datasets should be directed to CS, carlos.serrano.90@hotmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of the European University of Madrid (CIPI35/2019). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CS and JS-S: conceptualization and investigation. CS and JF: methodology. CS, JF, JS-S, and JG-U: writing and original draft preparation. LG and EH: writing, review, and editing. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

The authors express their gratitude to referees and the National Committee of Referees from the Spanish Football Federation.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 22 January 2021
doi: 10.3389/fpsyg.2021.636153

HIIT Models in Addition to Training Load and Heart Rate Variability Are Related With Physiological and Performance Adaptations After 10-Weeks of Training in Young Futsal Players

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Edited by:
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Specialty section:
This article was submitted to
Movement Science and Sport
Psychology,
a section of the journal
Frontiers in Psychology

Received: 01 December 2020
Accepted: 04 January 2021
Published: 22 January 2021

Citation:
Campos FS, Borszcz FK,
Flores LJF, Barazetti LK, Teixeira AS,
Hartmann Nunes RF and
Guglielmo LGA (2021) HIIT Models in
Addition to Training Load and Heart
Rate Variability Are Related With
Physiological and Performance
Adaptations After 10-Weeks of
Training in Young Futsal Players.
Front. Psychol. 12:636153.
doi: 10.3389/fpsyg.2021.636153

Introduction: The present study aimed to investigate the effects of two high-intensity interval training (HIIT) shuttle-run-based models, over 10 weeks on aerobic, anaerobic, and neuromuscular parameters, and the association of the training load and heart rate variability (HRV) with the change in the measures in young futsal players.

Methods: Eleven young male futsal players (age: 18.5 ± 1.1 years; body mass: 70.5 ± 5.7 kg) participated in this study. This pre-post study design was performed during a typical 10 weeks training period. HIIT sessions were conducted at 86% ($HIIT_{86}$; $n = 6$) and 100% ($HIIT_{100}$; $n = 5$) of peak speed of the FIET. Additionally, friendly and official matches, technical-tactical and strength-power training sessions were performed. Before and after the training period, all players performed the FIET, treadmill incremental, repeated sprint ability (RSA), sprint 15-m, and vertical jump tests (CMJ and SJ), and the HRV was measured. Training load (TL) was monitored using the session rating of perceived effort. Data analysis was carried out using Bayesian inference methods.

Results: The $HIIT_{86}$ model showed clear improvements for the peak oxygen uptake (VO_2peak), peak speed in the treadmill incremental test, first and second ventilatory thresholds, RSA best and mean times, CMJ, and SJ. The $HIIT_{100}$ model presented distinct advances in VO_2peak, peak speed in the treadmill incremental test, RSA mean time, and CMJ. Between HIIT models comparisons showed more favorable probabilities of improvement for $HIIT_{86}$ than $HIIT_{100}$ model in all parameters. TL data and HIIT models strongly explained the changes in the RSA mean and best times (R^2 = 0.71 and 0.87, respectively), as well as HRV changes, and HIIT models explained positively VO_2peak changes (R^2 = 0.72). All other changes in the parameters were low to moderately explained.

Conclusion: The $HIIT_{86}$ proved to be more effective for improving aerobic, RSA, and neuromuscular parameters than $HIIT_{100}$ during a typical 10-week futsal training period. So, strength and conditioning specialists prescribing shuttle-run intermittent exercises at submaximal intensities can manage the individual acceleration load imposed on athlete increasing or decreasing either the set duration or the frequency of change of direction during HIIT programming.

Keywords: sports, physical performance, high intensity interval training, shuttle-run, sprint

INTRODUCTION

Futsal is a team sport involving a complex range of high-intensity locomotor activities, requiring both aerobic and anaerobic fitness to cope with the multiple requirements of the match (Ribeiro et al., 2020). Research studies investigating this sport modality have increased significantly over the past two decades (Barbero-Alvarez et al., 2008; Castagna et al., 2009; De Oliveira Bueno et al., 2014; Caetano et al., 2015; Nakamura et al., 2020; Ribeiro et al., 2020), contributing to better understanding of the physical and skills requirements during the futsal match and organization of the training contents. Time motion analysis studies reported that during a single match, futsal players cover, on average, a total distance of 3000–4000 m, of which 8–13 and 5–9% are performed at high-speed running (HSR; >15.5 km/h) and sprinting (>18.3 km/h), respectively (Barbero-Alvarez et al., 2008; Castagna et al., 2009; De Oliveira Bueno et al., 2014). Repeated sprint sequences (RSS) with up to 2 to 3 sprints interspersed with 15 s of recovery are also frequently (∼80 occurrences per match) performed in futsal (Caetano et al., 2015). Similarly, the execution of deceleration and acceleration actions constitutes a critical part of the futsal players' work-rate (Ribeiro et al., 2020). Thus, HSR episodes, sprints, RSS, changes of directions (COD), and acceleration and deceleration actions are among the main types of activities that players should be prepared to perform efficiently. This information may be of practical relevance for the design of suitable training programs in order to enhance the main physical capacities related to successful performance in futsal.

The training intensity is among the first training variables to be manipulated in most physical conditioning programs for athletes (Buchheit and Laursen, 2013). The definition of number and duration of sets performed per training session is also a key component to determine the total training volume (i.e., total work duration performed) (Buchheit and Laursen, 2013). Thus, any manipulation in these variables, in an isolated or combined manner, will be decisive to determine the magnitude of adaptations to training (Buchheit and Laursen, 2013). High-intensity interval training (HIIT) and repeated-sprint/sprint interval training (RST/SIT) are currently among the most frequently used training models in physical conditioning programs of team sports players (Buchheit et al., 2008; Ferrari-Bravo et al., 2008; Buchheit and Laursen, 2013; McGinley and Bishop, 2016). The current evidence comparing RST/SIT vs. HIIT models demonstrates conflicting results, with some studies showing reduced gains (Buchheit et al., 2008) and others superior gains (Ferrari-Bravo et al., 2008) in performance after RST/SIT compared to HIIT models. Other studies have examined the effects of two work-matched HIIT models performed at different training intensities (McGinley and Bishop, 2016; Viaño-Santasmarinas et al., 2018). For instance, Viaño-Santasmarinas et al. (2018) did not find any improvements in aerobic fitness indices and RSA performance after two work-matched, HIIT models, performed at 85 and 95% of the final speed obtained in the 30–15 Intermittent Fitness Test (V_{IFT}) in professional handball players. This finding is in line with other research reporting no effect of training intensity on RSA performance outcomes following HIIT models (McGinley and Bishop, 2016). Thus, these two studies concluded that distinct training intensities during HIIT models produce similar performance enhancements when the same total exercise duration (i.e., *isotime*) is applied. While this *isotime* approach is a methodological strategy used in several studies to investigate the isolated effect of training intensity (McGinley and Bishop, 2016; Teixeira et al., 2018, 2019; Viaño-Santasmarinas et al., 2018), few studies have addressed the potential effects of distinct HIIT models varying in exercise intensity and total work duration on the athletic performance of team sport players (Ferrari-Bravo et al., 2008; Maggioni et al., 2019). Prior research studies investigating the integrative effects of these two key variables on the adaptive responses to distinct HIIT formats are limited to individual endurance sports athletes (Seiler et al., 2013).

Considering the multidirectional running pattern during futsal matches, HIIT strategies are usually composed of shuttle-runs in order to increase the specificity of these HIIT drills (Akenhead et al., 2014; Teixeira et al., 2018, 2019). In this sense, the simultaneous manipulation of the exercise intensity and total work duration during shuttle run HIIT models will have a direct influence on the magnitude and total number of acceleration and deceleration actions performed for each COD during a training session, respectively (Buchheit and Laursen, 2013; Akenhead et al., 2014). For instance, shuttle-run drills with a greater frequency of COD elicit an increased metabolic, cardiovascular, neuromuscular, and perceptual response in team sport athletes (Akenhead et al., 2014). Of interest, the number of COD performed during a short-term training period (5–6 weeks) was shown to be crucial to improve a variety of physical performance parameters in female team sport players (Sanchez-Sanchez et al., 2018; Teixeira et al., 2019). This research topic still needs further investigation, since the same effects observed in female athletes have not been noticed in male athletes (da Silva et al., 2015; Attene et al., 2016). Therefore, comparative studies examining the effects of two HIIT models at submaximal and maximal intensities with a contrasting total work duration in male futsal players could address practical questions on whether shuttle run HIIT programs, taking into account the physiological consequences of COD (Akenhead et al., 2014; Teixeira et al., 2018), would be more effective if performed at lower intensities with longer sets or at higher intensities with shorter set durations.

The dose-response relationship between the accumulated training load (TL) and performance adaptations is another relevant topic in the field of team sports, which deserves attention from coaches and sport scientists. The majority of studies examining the dose-response relationship have been primarily conducted with soccer and rugby players (Taylor et al., 2018; Daniels et al., 2019; Rabbani et al., 2019; Ellis et al., 2020). To date, few studies have investigated the dose-response relationship between TL and performance adaptations in futsal (Oliveira et al., 2013; Nakamura et al., 2020). Oliveira et al. (2013) did not find any association between TL and heart rate variability (HRV) and aerobic-anaerobic performance changes during seasonal training phases in professional futsal players. Differently, Nakamura et al. (2020) showed that accumulated TL negatively affected the physical and physiological adaptations of elite futsal players. Thus, further studies are still warranted to better understand the potential consequences of accumulated TL during the preseason phase on the subsequent changes in performance in futsal teams, especially in youth players.

The current study aimed to compare the effects of two shuttle run HIIT models performed at 86% ($HIIT_{86}$) and 100% ($HIIT_{100}$) of peak speed derived from the Futsal Intermittent Endurance Test (FIET, PS_{FIET}) with a total work duration of 16 and 8 min, respectively, implemented over a period of 10 weeks, on the HRV, aerobic fitness, RSA, and neuromuscular performance of young male futsal players. A second aim of this study was to examine the dose-response relationships between accumulated TL and changes in physical and physiological measures. Based on previous studies (Sanchez-Sanchez et al., 2018; Teixeira et al., 2018, 2019) our hypothesis was that the HIIT model with more COD and longer set duration ($HIIT_{86}$) would induce superior improvements on the selected physiological and physical measures than the model with less COD and shorter set duration performed at a higher intensity ($HIIT_{100}$).

MATERIALS AND METHODS

Subjects

The inclusion criteria for the study were regular participation in, at least, 75% of the training sessions during the period of investigation, not suffering from injuries during the same period, and not taking any medication that could alter the outcome of this study. Eleven young male futsal players (mean ± standard deviation; age: 18.5 ± 1.1 years; body mass: 70.5 ± 5.7 kg; height: 1.78 ± 0.07 m) from the U-20 professional futsal team of the first division of Paraná state – Brazil took part in this study. None of the players suffered any injury during the study period and all of them attended more than 75% of the training sessions during the 10 weeks of training. All players and their guardians were informed about the procedures of the study and signed an informed consent form. This study was approved by the local research ethics committee (n° 93777318.0.0000.0121) in accordance with current national and international laws and regulations governing the use of human subjects (Declaration of Helsinki II).

Experimental Design

A parallel 2-group longitudinal experimental study design was performed during 10 weeks from February to April of 2019 (5 weeks of pre-season and 5 weeks during the early in-season). During the study period, players were monitored over 105 training sessions, which were distributed into 16 sessions devoted to HIIT models (8 sessions for each group: $HIIT_{100}$ and $HIIT_{86}$) experimentally implemented for the purposes of this study, 23 sessions to develop strength-power characteristics, 56 sessions dedicated to futsal-specific technical-tactical skills, and 10 matches (3 friendly and 7 official matches; **Figure 1A**). Before and after the 10-week period, the following physical fitness tests were conducted on three separate days: first day (Monday): resting HRV and incremental treadmill test; second day (Wednesday): vertical jump (CMJ and SJ), straight 15-m sprint, and repeated sprint ability (RSA with COD: 8 x 10+20+10 m) tests; third day (Friday): FIET protocol (**Figure 1B**). Testing sessions were carried out in a laboratory and on an indoor futsal court, separated by 48 h between each session (**Figure 1B**), following the procedures of a previous study (Buchheit et al., 2008). Participants were allowed to drink water *ad libitum* during the field testing and training sessions. The internal training load of each player was monitored daily using the session rating of perceived exertion (s-RPE) during all training sessions and matches (Foster et al., 2001; Fanchini et al., 2016).

Training Intervention

During the intervention period, two different shuttle-run HIIT models were applied based on the individual PS_{FIET} of each player, and both training models were performed once a week. Due to the team's training schedule, the HIIT sessions started only in the 2nd week and ended in the 9th week of training (last week before the 10th congested week: 2 matches within a 7-day period). All HIIT sessions were carried out before the tactical-technical sessions in the morning period. The $HIIT_{86}$ model consisted of 4 sets of 4-min bouts performed at 86% of PS_{FIET} with 3 min of passive recovery between the sets, whereas the $HIIT_{100\%}$ model was composed of 8 sets of 60 s bouts at 100% of PS_{FIET} with 45 s of passive recovery between the sets. Each bout was characterized by 15 s of running effort followed by 15 s of passive rest. Thus, players performed 8 and 2 repetitions of 15 s shuttle runs (with a COD every 3.75 s) during each set of the $HIIT_{86\%}$ and $HIIT_{100\%}$ models, respectively (Teixeira et al., 2018, 2019). Consequently, all players performed a total of 128 and 64 accelerations and 96 and 48 decelerations/COD actions per training session during the $HIIT_{86\%}$ and $HIIT_{100\%}$ models, respectively. The average running pace performed by the athletes between the start and return lines for each training model was dictated by a prerecorded audio cue, emitting beeps every 3.75 s (Speaker, Satellite, Taiwan). The distance covered by each athlete

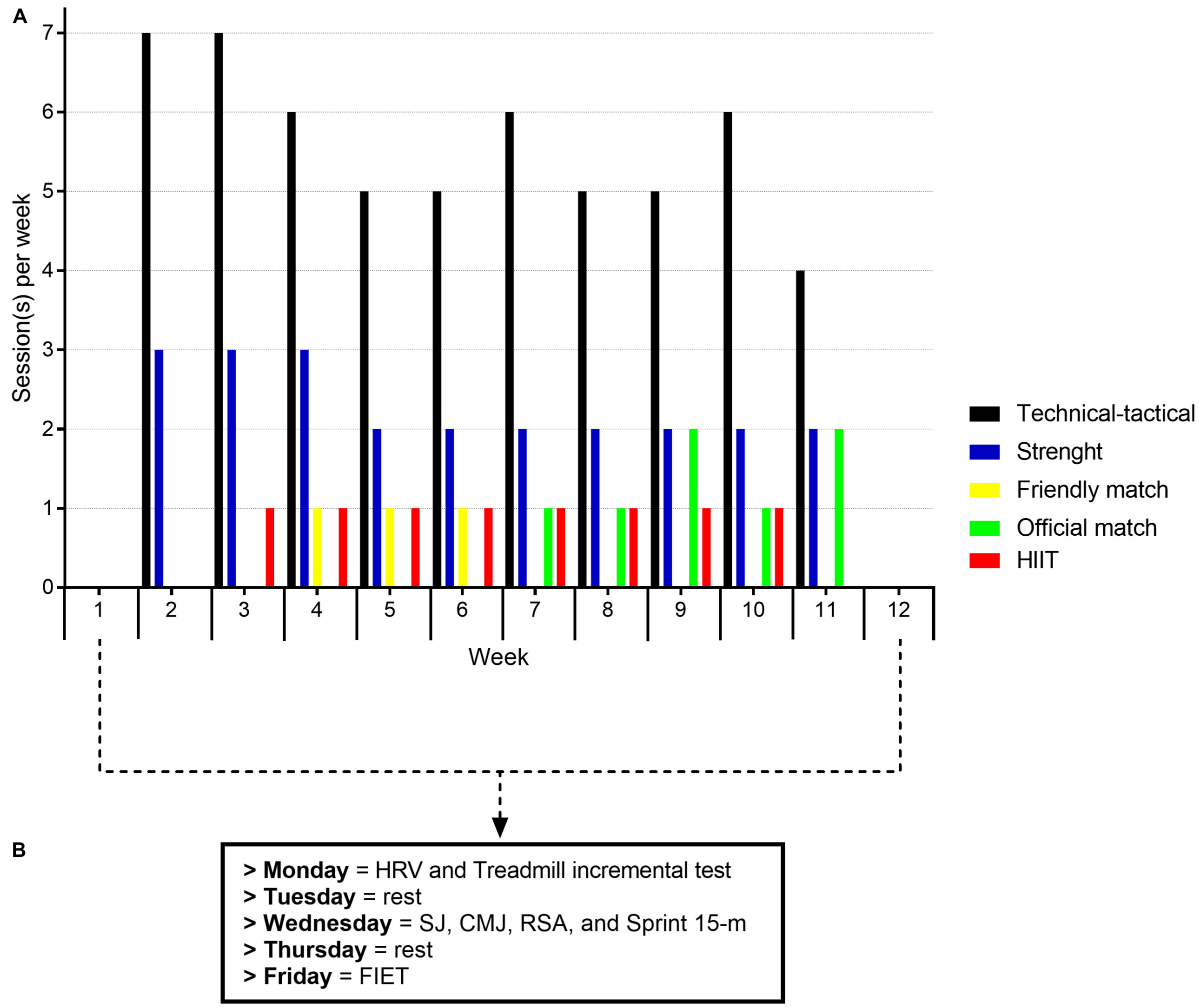

FIGURE 1 | Experimental design with the number of each training/match session type in each week **(A)**, and the testing sessions at pre and post 10 weeks of training **(B)**. HIIT, high intensity interval training; HRV, heart rate variability; SJ, squat jump; CMJ, counter movement jump; RSA, repeated sprint ability test; FIET, Futsal Intermittent Endurance Test.

during the training sessions was individualized according to their respective PS_{FIET}.

Treadmill Incremental Test

A progressive incremental exercise test was performed on a motorized treadmill (Imbramed ATL, Porto Alegre, Brazil). During the test the treadmill inclination was set at a 1% gradient with an initial speed of 9.0 km/h and then the treadmill speed was increased by 1.0 km/h every minute until volitional exhaustion (Kuipers et al., 2003). The peak speed ($PS_{TREADMILL}$) was calculated according to procedures described elsewhere (Kuipers et al., 2003). Each participant was verbally encouraged to deliver maximum effort during the incremental test. Respiratory gasses were measured breath by breath during the test using a calibrated online metabolic system (K5; COSMED, Rome, Italy). For peak oxygen uptake (VO_2peak), and first and second ventilatory threshold (VT_1 and VT_2, respectively) determination, all gas exchange data were filtered using K5 software (Omnia; COSMED, Rome, Italy) to discard outlier points. Subsequently, the data were reduced to means of 15 s for further analysis. The highest 15 s value of oxygen uptake (VO_2) was considered as VO_2peak. For VT_1 and VT_2 determination the ventilation/oxygen uptake (VE/VO_2) and ventilation/carbon dioxide production (VE/VCO_2) equivalents were used. The first abrupt increase in VE/VO2 without a concomitant increase in VE/VCO2 was considered the VT_1 (Caiozzo et al., 1982), and the first abrupt increase in VE/VCO2 was considered the VT_2 (McLellan, 1985). The speed at each threshold was determined.

Futsal Intermittent Endurance Test (FIET)

The FIET consisted of shuttle-run bouts of 45 m (i.e., 3 × 15 m) performed at progressive speeds until voluntary exhaustion (Castagna and Barbero Álvarez, 2010). Every 45 m, players were allowed to actively rest for 10 s. After each 8 × 45 m bout, players passively rested for 30 s. The starting velocity was set at

9.0 km/h with speed increments of 0.33 km/h during the first 9 × 45 m bouts. After 9 × 45 m bouts, the increment changed to 0.20 km/h every 45 m until exhaustion. The speed was controlled by prerecorded audio cues (Speaker, Satellite, Taiwan). The test was finished when participants did not reach the front line in time with the beeps for 2 consecutive repetitions. The peak speed (i.e., PS_{FIET}) reached at the end of the test by the athletes was reported as the performance criterion for the FIET.

Vertical Jumping Tests

Vertical jump height (cm) was determined using the counter movement jump (CMJ) and the squat jump (SJ). In the CMJ, the participants were instructed to execute a downward movement followed by a complete extension of the legs and were free to determine the countermovement amplitude to avoid changes in jumping coordination. In the SJ, the participants were required to remain in a static position with a 90° knee flexion angle for 3 s before jumping, without any preparatory movements. The CMJ and SJ were executed with the hands fixed on the hips. All jumps were performed on a contact platform (CEFISE, Brazil). A total of 3 attempts were allowed for each jump with a 45 s rest interval between attempts. The best CMJ and SJ attempts were used for further analysis (Bosco et al., 1983).

Straight 15-m Sprint Test

All players performed three maximal 15 m sprints with at least 2 min of passive rest between the three trials (Cronin and Hansen, 2005). Sprint time was recorded using a photocell system (Microgate, Italy) with timing gates placed at the 0 m (i.e., starting gate) and 15 m marks (i.e., finishing gates). All sprinting tests were conducted on an indoor futsal court, thus eliminating any potential effect of the environmental conditions. The best sprint time was retained for further analysis.

Repeated Sprint Ability Test

The 40-m RSA test consisted of 8 × 40 m sprints separated by 20 s of passive recovery (Baker et al., 1993). The athlete stared 0.5 m behind the start line and times were recorded electronically via photocells (Microgate, Italy). Before the RSA test, players performed a standardized 5-min warm-up of progressive runs and accelerations that were administered by the team's physical trainer. Before starting, athletes were instructed to run as fast as possible between two lines placed 20 m apart, with the start/finish line (and the photocells) placed at the midpoint of the course. Each participant sprinted 10 m from the start/finish line to the end of the course, turned 180°, sprinted 20 m to the other end of the course, turned 180°, and sprinted 10 m back through the start/finish line. Following each sprint, the athlete decelerated and walked to the starting line in readiness for the subsequent sprint. Five seconds prior to the next sprint, the athletes assumed the starting position and a 3 s countdown was provided to commence again. The best (RSA_{BEST}) and mean sprint times (RSA_{MEAN}) were recorded as the performance indices.

Heart Rate Variability (HRV)

The resting HRV was obtained by time elapsed between two successive R-waves of the QRS signal of the heart rate (R-R intervals) using an RS800cx (Polar Electro, Finland) heart rate monitor. The resting HRV was recorded on Monday mornings at 7:00 a.m., before and after the 10-week period (**Figure 1B**). During the RR recordings, all players remained at rest for 5 min in the supine position following the standards set by the Task Force (Task Force, 1996). The first 2 min were excluded (signal stabilization), and the remaining 3 min were used to calculate the resting HRV indices. Correction of ectopic beats and/or erroneous signals was performed automatically using the manufacturer's software (Kubios HRV Analysis, Finland) with a degree of correction < 3% for all recordings, and when necessary, manual correction of artifacts was performed. The resulting R-R intervals were examined in only 1 time-domain index (i.e., root mean square difference of successive normal R-R intervals [rMSSD]). The rMSSD has been reported to reflect vagal modulation and to be related to training-induced effects (Buchheit et al., 2009). The delta change (post – pre training values) in rMSSD (ΔrMSSD) was used for analysis.

Training Load (TL)

The internal TL was measured using the s-RPE method (Foster et al., 2001). Thirty minutes after the completion of each training session and matches, players were requested to report RPE for the intensity of the training sessions and matches using a 0-100 point RPE scale proposed by Borg and Borg (2002) and recently validated by Fanchini et al. (2016). The 0-100 scale value reported by the players was divided by 10 (i.e., RPE: 75 ÷ 10 = 7.5), and this value was multiplied by session duration, in minutes, to calculate the TL of each training session and matches. When two training sessions were performed on the same day, the TL was summed to create the daily TL. During each training week, the daily TL was summed to create the total weekly TL.

Statistical Analysis

The analysis was performed using established Bayesian inference methods. The physiological and performance data were analyzed as percentage deltas of pre-measure $\left(\Delta\% = \left((Post - Pre) \big/ Pre\right) \times 100\right)$ (except for HRV that was analyzed in raw units). Analysis was performed using the linear modeling procedure, with the training models (i.e., $HIIT_{100}$ and $HIIT_{86}$), and the baseline measures centered to the mean of all study subjects included as fixed effects. Additionally, a dose-response analysis was used to verify the relationship of responses to training with the TL and HRV measures. Thus, the training models, delta in the HRV or training load measure, and interaction between training models × HRV/training load were inserted in the model as fixed effects. The Bayesian R^2 was calculated as an estimate of the proportion of variance explained for new data (Gelman et al., 2019). Model fitting is performed using Markov Chain Monte Carlo (MCMC) methods, more specifically the No-U-Turn (NUTS) sampler implemented in Stan. Student t-distribution (df = 3, μ = 0, and σ = 10) priors were set to be non-informative, so that their influence on the estimates was relatively small (Gelman et al., 2008). Unless otherwise stated, all observed data are reported as means ± standard deviations (SD), and the posterior data as means with 90% highest density credible intervals (CIs) for pre to post changes, and medians with 90% equal tailed CIs for dose-response analysis. The CI represents there is a 90% probability that the parameter is contained within a 90% CI (Morey et al., 2016).

Inferences about the effects were made by interpreting the 90% CI in relation to the region of practical equivalence (ROPE). We specified our ROPE as 0.2 × between-subjects SD (Hopkins et al., 2009). Thus, the ROPEs for VO_2peak, PS_{FIET}, $PS_{TREADMILL}$, VT_2, VT_1, RSA_{BEST}, RSA_{MEAN}, sprint 15-m, CMJ, SJ, and HRV are ± 1.8%, ± 0.9%, ± 1.0%, ± 2.0%, ± 2.3%, ± 0.5%, ± 0.7%, ± 0.9%, ± 1.7%, ± 2.1%, and ± 6.1 ms, respectively. Therefore, an effect was deemed "trivial" when the two bounds of the 90% CI were within the ROPE. Conversely, when the CI overlapped the ROPE the effects were interpreted as "undecided" (Kruschke, 2018). When the two 90% CI bounds were out of the ROPE the effect was deemed as "beneficial" or "harmful", when positive and negative, respectively; except for RSA_{MEAN}, RSA_{BEST}, and Sprint 15-m where negative and positive effects were "beneficial" and "harmful", respectively. Additionally, based on the posterior distributions, we calculated the probability (%) of the effect to be harmful/trivial/beneficial. Statistical analyses were performed using statistical software R (v4.0; R Core Team (2020), Vienna, Austria) and its graphical interface RStudio (v1.2.5). The package "brms" (Bürkner, 2017) allowing fitting of Bayesian multilevel models using "Stan" (Gelman et al., 2015) was used for analysis.

RESULTS

Descriptive statistics of observed data (mean ± standard deviation [range]) for aerobic, RSA, sprint, and vertical jump performances before (pre-) and after (post-training) the training period (10 weeks) in each HIIT model are presented in **Table 1**.

Changes for the parameters determined during the FIET and treadmill incremental tests are displayed in **Figure 2**. The $HIIT_{100}$ model showed clear beneficial effects (i.e., the full 90% CI boundaries out of ROPE) for VO_2peak and $PS_{TREADMILL}$ measurements. For the $HIIT_{86}$ model, clear beneficial changes occurred in the VO_2peak, $PS_{TREADMILL}$, VT_2, and VT_1. For the $HIIT_{100}$ model, VT_2 and VT_1 changes were well supported within the ROPE, nevertheless, these effects are inconclusive because they overlapped the lower and upper ROPE boundaries. For PS_{FIET}, both HIIT models presented no clear improvements, although the probabilities were high for improvement (> 89%), low for trivial (< 8%), and negligible for impairment (< 2.6%). Between HIIT models comparisons showed more favorable probabilities in favor of $HIIT_{86}$ than $HIIT_{100}$ in all parameters; however, clearly more favorable changes for the $HIIT_{86}$ model compared to the $HIIT_{100}$ model were observed only for $PS_{TREADMILL}$, VT_2, and VT_1 (probabilities > 96%).

Pre to post changes for RSA_{MEAN}, RSA_{BEST}, 15-m sprint, CMJ, and SJ measures are summarized in **Figure 3**. The $HIIT_{100}$ model showed clear beneficial effects for RSA_{MEAN} and CMJ

TABLE 1 | Observed means ± SD (minimum – maximum) of physiological, and performance parameters of futsal players in each HIIT model pre and post ten weeks of training and the changes.

Parameter	$HIIT_{100}$ (*n* = 5)			$HIIT_{86}$ (*n* = 6)		
	Pre	Post	Δ Pre-Post	Pre	Post	Δ Pre-Post
VO_2peak (mL/kg/min)	56.5 ± 5.2 (50.7–62.2)	59.9 ± 4.1 (54.9–64.4)	3.5 ± 1.4 (1.6–4.6)	63.4 ± 3.5 (57.3–66.7)	66.7 ± 2.6 (63.2–70.0)	3.3 ± 1.4 (2.0–5.9)
PS_{FIET} (km/h)	15.7 ± 0.5 (14.8–16.2)	16.4 ± 0.8 (15.4–17.2)	0.8 ± 0.6 (0.2–1.6)	16.5 ± 0.7 (15.6–17.4)	17.0 ± 0.6 (16.0–17.8)	0.5 ± 0.7 (0.00–1.8)
$PS_{TREADMILL}$ (km/h)	16.8 ± 1.4 (15.2–18.0)	17.8 ± 1.0 (16.6–19.1)	1.0 ± 0.7 (0.1–1.8)	17.3 ± 1.5 (15.6–19.1)	18.9 ± 0.3 (18.5–19.3)	1.6 ± 1.2 (0.0–3.1)
VT_2 (km/h)	14.8 ± 1.6 (13.0–16.0)	15.0 ± 1.7 (13.0–16.0)	0.2 ± 0.8 (−1.0–1.0)	15.4 ± 1.7 (14.0–18.0)	16.8 ± 0.8 (13.0–16.0)	1.3 ± 0.8 (0.0–2.0)
VT_1 (km/h)	11.5 ± 1.1 (10.0–13.0)	11.7 ± 1.6 (10.0–13.0)	0.2 ± 1.3 (−2.0–1.0)	11.8 ± 1.7 (11.0–15.0)	13.3 ± 1.1 (12.0–15.0)	1.5 ± 1.0 (0.0–3.0)
RSA_{BEST} (s)	8.12 ± 0.20 (7.98–8.47)	8.13 ± 0.22 (7.94–8.50)	0.01 ± 0.07 (−0.11–0.05)	8.28 ± 0.24 (7.86–8.56)	8.06 ± 0.37 (7.47–8.56)	−0.22 ± 0.14 (−0.39–0.00)
RSA_{MEAN} (s)	8.69 ± 0.36 (8.33–9.24)	8.43 ± 0.31 (8.13–8.87)	−0.26 ± 0.10 (−0.37–−0.12)	8.50 ± 0.18 (8.20–8.71)	8.25 ± 0.31 (7.81–8.64)	−0.26 ± 0.20 (−0.44–0.09)
Sprint 15-m (s)	2.50 ± 0.13 (2.35–2.69)	2.42 ± 0.06 (2.32–2.47)	−0.08 ± 0.11 (−0.27–0.00)	2.43 ± 0.08 (2.33–2.53)	2.37 ± 0.09 (2.29–2.54)	−0.05 ± 0.08 (−0.17–0.05)
CMJ (cm)	32.7 ± 1.5 (31.3–34.3)	35.5 ± 1.5 (34.2–37.8)	2.8 ± 1.9 (0.0–4.9)	33.4 ± 3.7 (27.1–37.1)	38.0 ± 4.7 (28.6–41.0)	4.6 ± 2.5 (1.5–8.6)
SJ (cm)	31.2 ± 2.5 (27.9–33.8)	32.4 ± 1.8 (30.5–34.6)	1.2 ± 2.2 (−2.7–2.7)	31.6 ± 4.2 (25.6–36.3)	36.6 ± 4.1 (29.3–40.1)	5.0 ± 4.3 (−1.2–11.7)
HRV (ms)	61.0 ± 21.4 (34.4–80.6)	104.4 ± 20.8 (87.1–137.7)	43.4 ± 40.1 (4.4–103.3)	70.5 ± 38.2 (17.2–120.3)	109.2 ± 32.9 (54.6–150.0)	38.7 ± 25.4 (11.2–86.1)

All data are means ± SD (minimum – maximum) in raw units. VO_2peak, peak oxygen uptake; PS_{FIET}, peak speed of FIET test; $PS_{TREADMILL}$, peak speed of treadmill incremental test; VT_2, second ventilatory threshold; VT_1, first ventilatory threshold; RSA_{BEST}, best sprint time in the RSA test; RSA_{MEAN}, mean sprint time in the RSA test; Sprint 15-m, best time in 15 meters; CMJ, counter movement jump; SJ, squat jump; HRV, heart rate variability; Δ, change pre to post.

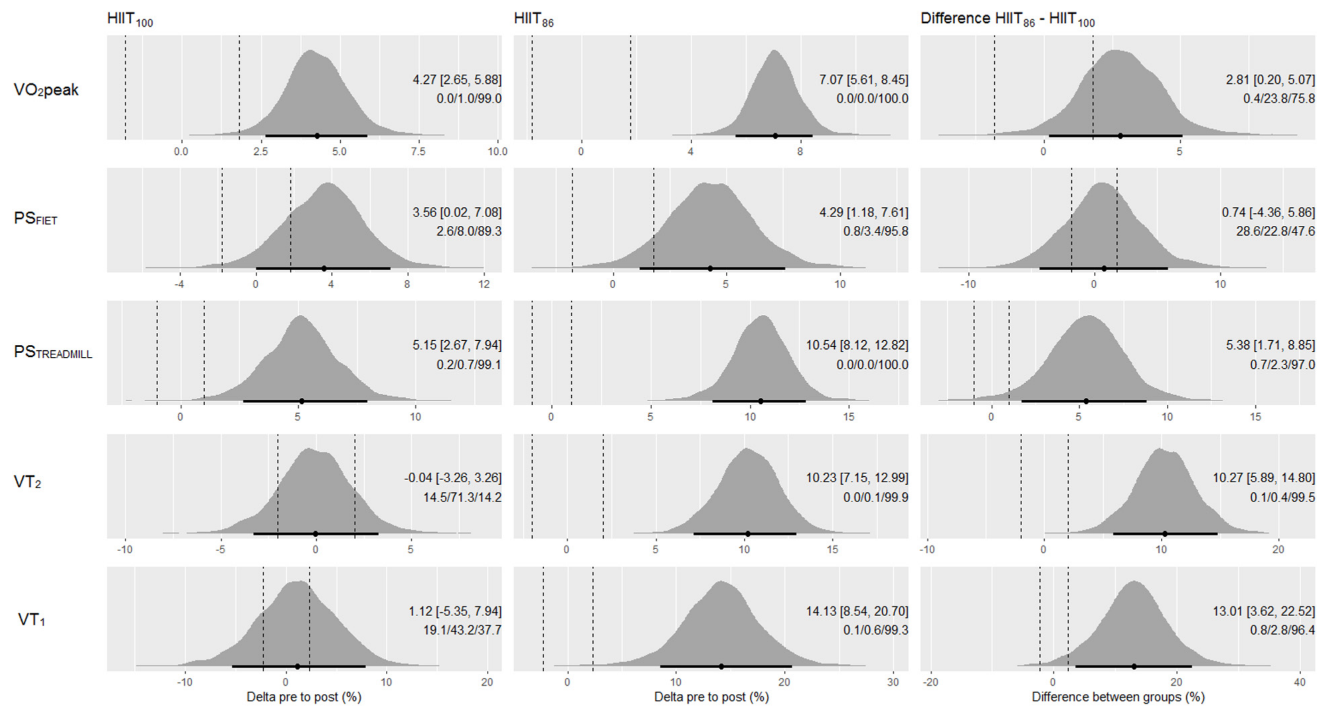

FIGURE 2 | Posterior density distributions and the respective means with 90% credible intervals of the pre to post changes in VO_2peak, PS_{FIET}, $PS_{TREADMILL}$, VT_2, and VT_1 (upper to lower panels, respectively) in each HIIT model, and the comparison of changes between models. The effects are adjusted to baseline mean of all study subjects. Black points and error bars are the posterior mean change and 90% credible intervals, respectively. Vertical dashed lines are the lower and upper boundaries of the ROPE (i.e., 0.2× between subjects SD). The texts in each graph are the means (90% CI) and probabilities against ROPE.

measurements, considerable probability of improvement for 15-m sprint time (84%), and inconclusive effects for RSA_{BEST} and SJ. The $HIIT_{86}$ model showed clear beneficial effects for all anaerobic running measurements, except the 15-m sprint time, where a high probability of improvement (92.1%), small/moderate of being trivial (7.1%), and negligible of being harmful (0.8%) were observed. Between HIIT models comparisons showed clearly more favorable changes for the $HIIT_{86}$ than $HIIT_{100}$ model in the RSA_{BEST} and SJ measures (probabilities > 96%). All other effects between model were deemed inconclusive.

Pre to post change in the HRV revealed clear beneficial changes in both training models, with probabilities > 98.1% (**Figure 4**). However, no evidence of superiority of one HIIT model over the other was observed.

The total weekly TLs for both $HIIT_{86}$ (black bars) and $HIIT_{100}$ (gray bars) models during each training week are presented in **Figure 5A**. The total accumulated TLs derived from (i) all training sessions and matches (#), (ii) all training sessions and matches without HIIT sessions ($), and (iii) HIIT sessions (*) are presented in **Figure 5B**. For the entire training period, the total accumulated TL from all training sessions and matches showed a mean difference [90% CI] of −1836 [−8279, 4340] arbitrary units (a.u.) between $HIIT_{86}$ and $HIIT_{100}$ models, with a probability of 55.9% of the TL being lesser in the $HIIT_{86}$ than $HIIT_{100}$. The total accumulated TL of all training sessions and matches without HIIT was lesser in the $HIIT_{86}$ than $HIIT_{100}$ (−2671 [90% CI; −4137, 9004] a.u.), with a probability of TL being lesser in the $HIIT_{86}$ of 76.5%. Contrarily, as expected, the total accumulated TL over the 8 HIIT sessions was two-fold higher in the $HIIT_{86}$ than the $HIIT_{100}$ model (difference: 778 [90% CI; 609, 941] a.u.), with 100% probability of being higher in the $HIIT_{86}$ model.

Since the players followed the same training routine, with the exception of the HIIT sessions, the dose-response relationship between RPE-based TL and Δ rMSSD with changes in aerobic, RSA, 15-m sprint, and jump performances was carried out, adding HIIT models as a covariate in the final model. The regression outputs between total weekly TL (10-week average) and ΔrMSSD in addition to HIIT type with changes in performance measures are displayed in **Figures 6**, **7**, respectively. Total weekly TL and HIIT model accounted for 25 to 87% of the variance (i.e., Bayesian R^2) in aerobic fitness, RSA, and power-speed-related performance changes. The explained variance derived from regression models using ΔrMSSD and HIIT type as covariates ranged from 26 to 72%.

DISCUSSION

The current study aimed to compare the effects of two shuttle run-based HIIT models of varying intensity and total work duration ($HITT_{86}$: 16 min vs. $HITT_{100}$: 8 min) on aerobic, HRV, RSA, and neuromuscular performance outcomes in junior male futsal players. The dose-response relationship between RPE-based TL and changes in performance was

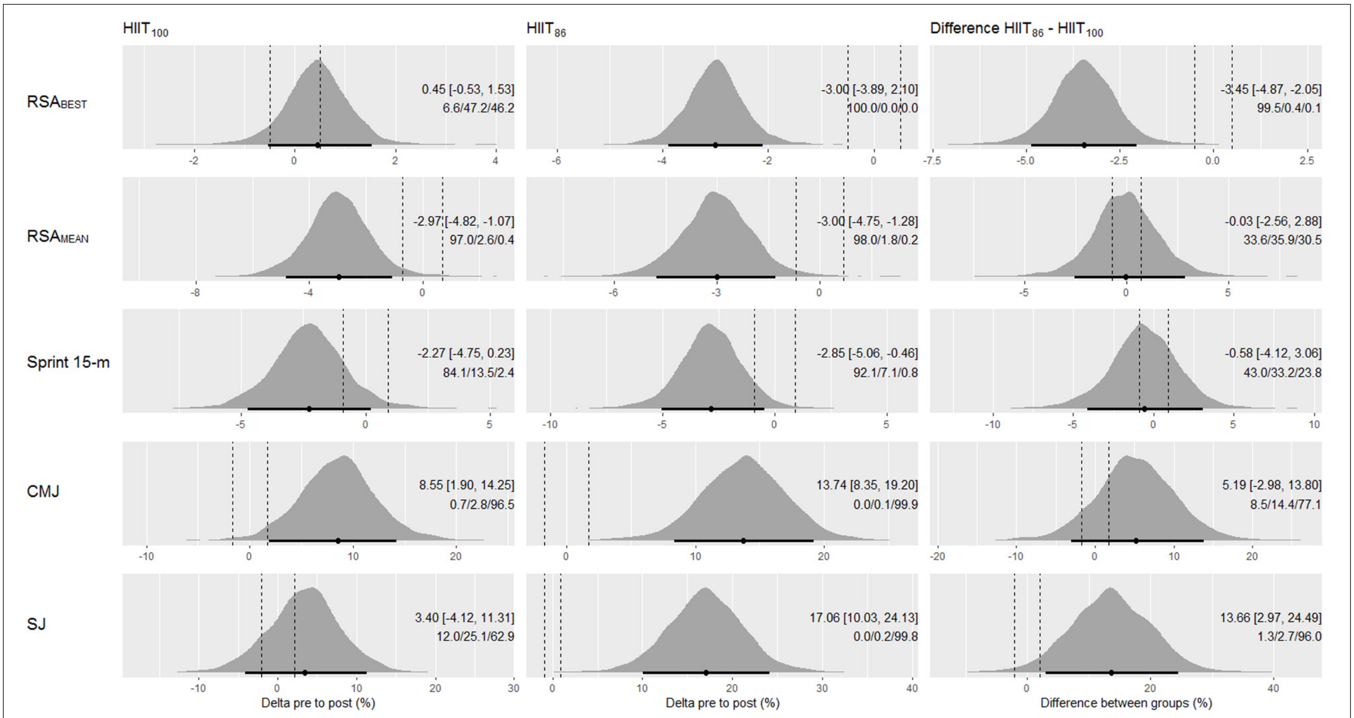

FIGURE 3 | Posterior density distributions and the respective means with 90% credible intervals of the pre to post changes in RSA_{BEST}, RSA_{MEAN}, Sprint 15-m, CMJ, and SJ (upper to lower panels, respectively) in each HIIT model, and the comparison of changes between models. The effects are adjusted to baseline mean of all study subjects. Black points and error bars are the posterior mean change and 90% credible intervals, respectively. Vertical dashed lines are the lower and upper boundaries of the ROPE (i.e., 0.2× between subjects SD). The texts in each graph are the means (90% CI) and probabilities against ROPE.

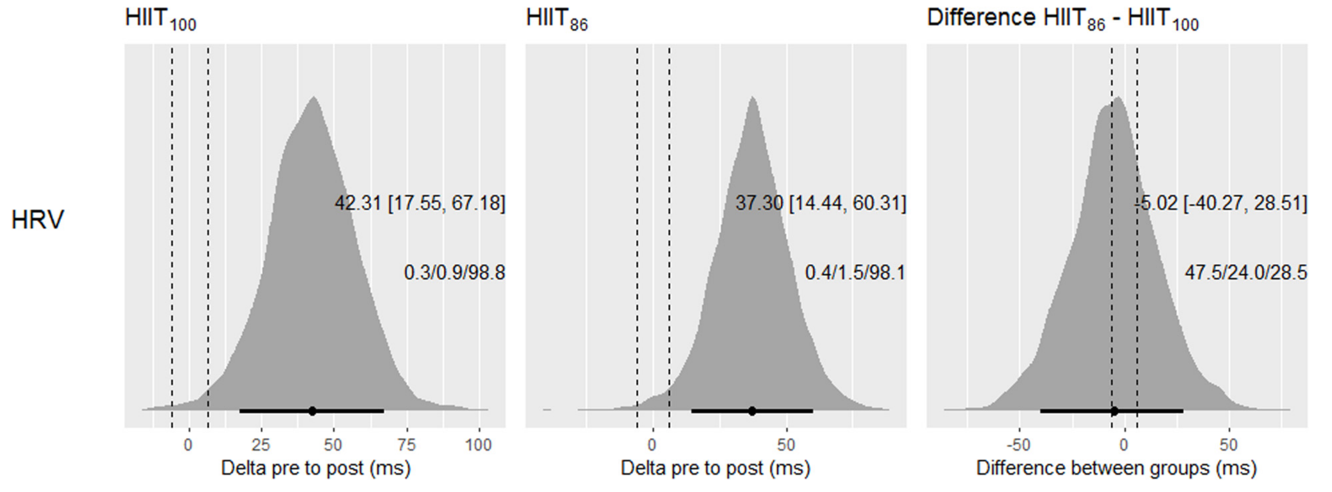

FIGURE 4 | Posterior density distributions and the respective means with 90% credible intervals of the pre to post changes in HRV in each HIIT model, and the comparison of changes between models. Black points and error bars are the posterior mean change and 90% credible intervals, respectively. Vertical dashed lines are the lower and upper boundaries of the ROPE (i.e., 0.2× between subjects SD). The texts in each graph are the means (90% CI) and probabilities against ROPE.

also examined. The main findings of this study showed that after 10-weeks of futsal training: (i) the $HIIT_{86}$ model was clearly more effective at improving the $PS_{TREADMILL}$ (Δ = 5.4%), VT_2 (Δ = 10.0%), VT_1 (Δ = 13.0%), RSA_{BEST} time (Δ = −3.5%), and SJ height (Δ = 13.7%) than the $HIIT_{100}$; (ii) RPE-based TL in association with HIIT type explained 71% to 87% of the inter-individual variation in RSA performance changes, while the explained variance for the other parameters was smaller (25–59%); and (iii) changes in HRV along with HIIT type accounted for 72% of inter-individual variance in VO_2peak changes following the training period.

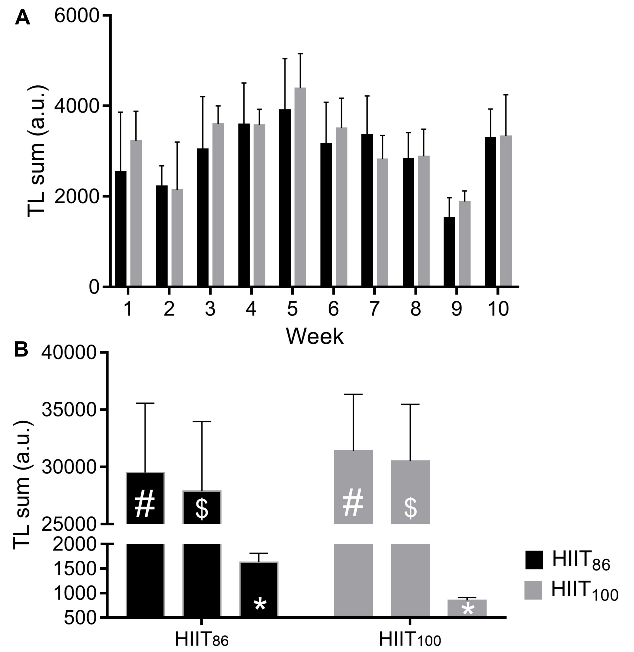

FIGURE 5 | Observed means ± SD of training load sum in each week **(A)** and the accumulated sum over 10 weeks of all training/match sessions [#], all training/match sessions without HIIT [$], and only HIIT sessions [*] **(B)**. Bars and error bars are the mean and SD, respectively. a.u., arbitrary units.

Comparative studies examining the effectiveness of different training models are increasingly needed and recommended to help guide decision-making of strength and conditioning coaches during the planning of training programs with futsal players (Buchheit et al., 2008; Ferrari-Bravo et al., 2008; Sanchez-Sanchez et al., 2018). Training intensity and total work duration are two key variables commonly altered in order to increase the physical capacity of athletes (Buchheit and Laursen, 2013) and, therefore, they need to be well managed during HIIT programming. In the current study, the improvements in physical fitness indices were specific to training type. Our data indicated that the $HIIT_{86}$ model clearly improved (i.e., full 90% CI out of ROPE) the majority of the physical and physiological parameters measured (9 out of 11 parameters; **Figures 2**, **3**, **4**) compared to the $HIIT_{100}$ model (5 out of 11 parameters; **Figures 2**, **3**, **4**). In addition, the $HIIT_{86}$ model induced larger improvements in aerobic, RSA, and neuromuscular performance outcomes than the $HIIT_{100}$ model. The results presented herein suggest that the $HIIT_{86}$ training, comprising longer sets at a lower intensity, was more effective to enhance performance than the $HITT_{100}$ composed of shorter sets and more intense running efforts. Similarly, Buchheit et al. (2008) also reported greater performance adaptations after HIIT models performed at lower running intensities (i.e., close to 90–95% V_{IFT}) in male adolescent handball players. Seiler et al. (2013) also showed that training intensity and total work duration influenced the magnitude of adaptive responses following distinct HIIT models (4 × 4 min; 4 × 8 min; 4 × 16 min) in trained cyclists. On the other hand, current studies published in the literature suggests that HIIT models of different training intensities induced similar performance enhancements in male adults (McGinley and Bishop, 2016; Viaño-Santasmarinas et al., 2018). Some differences between these studies should be addressed. For instance, the total work duration in our training design varied between training groups, while prior studies used an *isotime* approach (i.e., matched-work) only varying exercise intensity (Buchheit et al., 2008; Seiler et al., 2013; McGinley and Bishop, 2016; Viaño-Santasmarinas et al., 2018). In addition, the reference running speed used for training prescription also differed between the cited studies (Buchheit et al., 2008; Viaño-Santasmarinas et al., 2018). Thus, comparison between the current results and those observed in prior studies should be interpreted with caution due to differences in sample characteristics (e.g., chronological age), methodological issues, sport modality, training demands, and performance levels.

It is well known and accepted that aerobic fitness and RSA performance are two discriminant physical qualities of the competitive level in futsal (Álvarez et al., 2009; Pedro et al., 2013; Ayarra et al., 2018). Thus, training strategies targeting the development of these physical qualities simultaneously are essential. Our findings indicating the superiority of $HIIT_{86}$ over $HIIT_{100}$ at improving aerobic fitness, RSA, and vertical jump performance suggest that this training type (submaximal runs at 86% PS_{FIET} and longer sets) should be preferentially used with young futsal players. The specific adaptations in physical performance following the $HIIT_{86}$ and $HITT_{100}$ models could potentially be related to differences in total work duration between the models (Teixeira et al., 2018, 2019). Due to its higher total running volume (16 vs. 8 min), the $HIIT_{86}$ implies a greater number of COD performed in a single session (96 vs. 48 turns), increasing the total time that athletes spent accelerating per running bout compared to the $HIIT_{100}$ model. Akenhead et al. (2014) showed that the number of turns and time spent accelerating ($> \pm 1$ m·s^{-2}) are linearly related during shuttle run drills. Prior research has indicated that accumulated individual acceleration load is positively associated with changes in aerobic fitness and neuromuscular measures in professional soccer players (Clemente et al., 2019). Given that acute and chronic responses to training are dependent on acceleration load accumulated during multidirectional drills (Akenhead et al., 2014; Clemente et al., 2019), practitioners and coaches can increase or decrease the acceleration load accumulated by athlete during shuttle run-based HIIT varying either set duration as in this study or COD frequency per running bout (Sanchez-Sanchez et al., 2018; Teixeira et al., 2018, 2019). To date, to the best of our knowledge, this is the first study demonstrating that a HIIT model with more directional changes leads to superior gains in physical performance in a sample of aerobically well-trained male futsal players (VO_2peak > 55 mL/kg/min at baseline). Previous studies published on this research topic did not show any further performance gain after different shuttle run training models varying the number of COD required per running bout in male soccer and basketball players (da Silva et al., 2015; Attene et al., 2016). Of interest, the same $HIIT_{86}$ model used here was also applied in a sample of female futsal players (VO_2peak: 47–49 mL/kg/min at baseline) (Teixeira et al., 2018, 2019). The

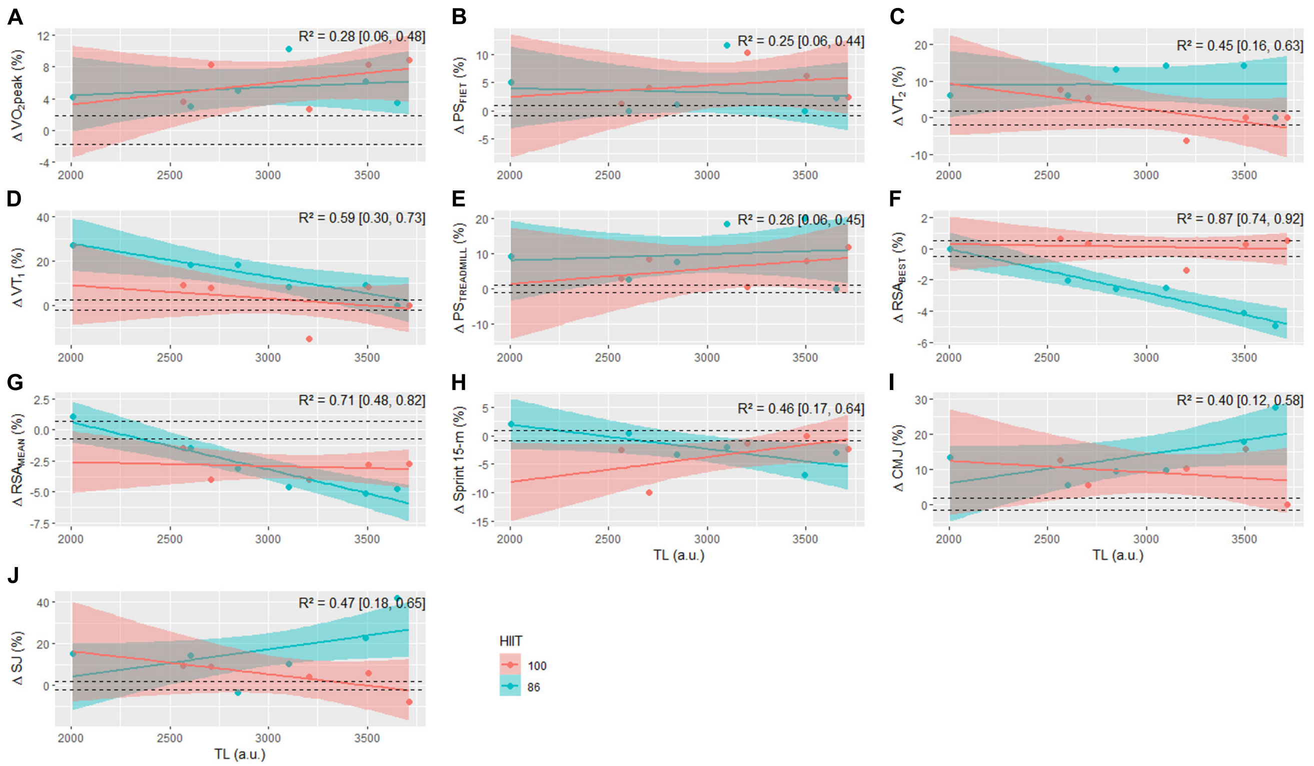

FIGURE 6 | Posterior regression medians with 90% credible intervals between pre-to-post changes in VO_2peak **(A)**, PS_{FIET} **(B)**, VT_2 **(C)**, VT_1 **(D)**, $PS_{TREADMILL}$ **(E)**, RSA_{BEST} **(F)**, RSA_{MEAN} **(G)**, Sprint 15-m **(H)**, CMJ **(I)**, and SJ **(J)** for each HIIT model with training load. R^2, Bayesian variance explained. Horizontal dashed lines are the lower and upper boundaries of the ROPE (i.e., 0.2× between subjects SD).

current and prior studies (Teixeira et al., 2018, 2019) showed a greater improvement in $PS_{TREADMILL}$ and RSA performance after $HIIT_{86}$ model. This demonstrates the consistency and effectiveness of this training model ($HIIT_{86}$) to improve these physical qualities in age-matched male and female futsal players. At the same time, male and female futsal athletes of similar ages can display distinct neuromuscular performance adaptations (i.e., changes in SJ and CMJ height) following $HIIT_{86}$, with male athletes in the current study being more responsiveness (Δ = 13–17%) than female athletes (Δ = 8–9%) in the study of Teixeira et al. (2018). Therefore, it should be highlighted that any generalization of our findings to other samples of futsal (male or female; young or adult) or other indoor team sports (e.g., basketball and handball) would be a hasty inference, since differences related to age, gender and sport demand in terms of workload and training content distribution during a typical training period could influence the effectiveness of this $HIIT_{86}$ model in these other sports scenarios.

From the present results on RPE-based TL and changes in physical performance, it is possible to make inferences about the dose-response relationship during the training process. The present study suggests that TL in addition to training type ($HIIT_{86}$ and $HIIT_{100}$) accounted for a large portion of the inter-individual variance in RSA (71–87%), 15-m Sprint (46%), and vertical jump (40–47%) performance changes. A positive linear dose-response relationship between TL and changes in these performance measures was found for the $HIIT_{86}$ model, while no (RSA performance) or negative (sprint and vertical jump) relationships were identified for the $HIIT_{100}$ model. These findings are of practical relevance for practitioners and coaches. First, players in both $HIIT_{86}$ and $HIIT_{100}$ models with a similar total TL displayed a distinct adaptive response (especially for RSA_{BEST} and SJ performance), highlighting that the quality/specificity of the training stimuli is the most relevant component of the training process (Sanchez-Sanchez et al., 2018). In this case, the increased number of COD in the $HIIT_{86}$ model (longer sets) may have been decisive to induce superior gains in performance. Second, players who accumulated higher training loads in the $HIIT_{86}$ model demonstrated the largest improvements in RSA, 15-m Sprint, and vertical jump performance, while the opposite was observed for the $HIIT_{100}$ model. Although these results cannot be easily explained from the data analysis employed in our study, it is possible to suggest that the training loads derived from other training strategies (technical-tactical, strength-power, friendly and official matches) may have influenced the players' adaptive response to training. For instance, players in the $HIIT_{100}$ model tended to accumulate a higher (with a 73% probability) TL derived from these other training contents (i.e., not involving HIIT sessions) than the $HIIT_{86}$ model (**Figure 5**).

The explained variances derived from regression models (TL and HIIT type inserted as covariates) for the changes in maximal

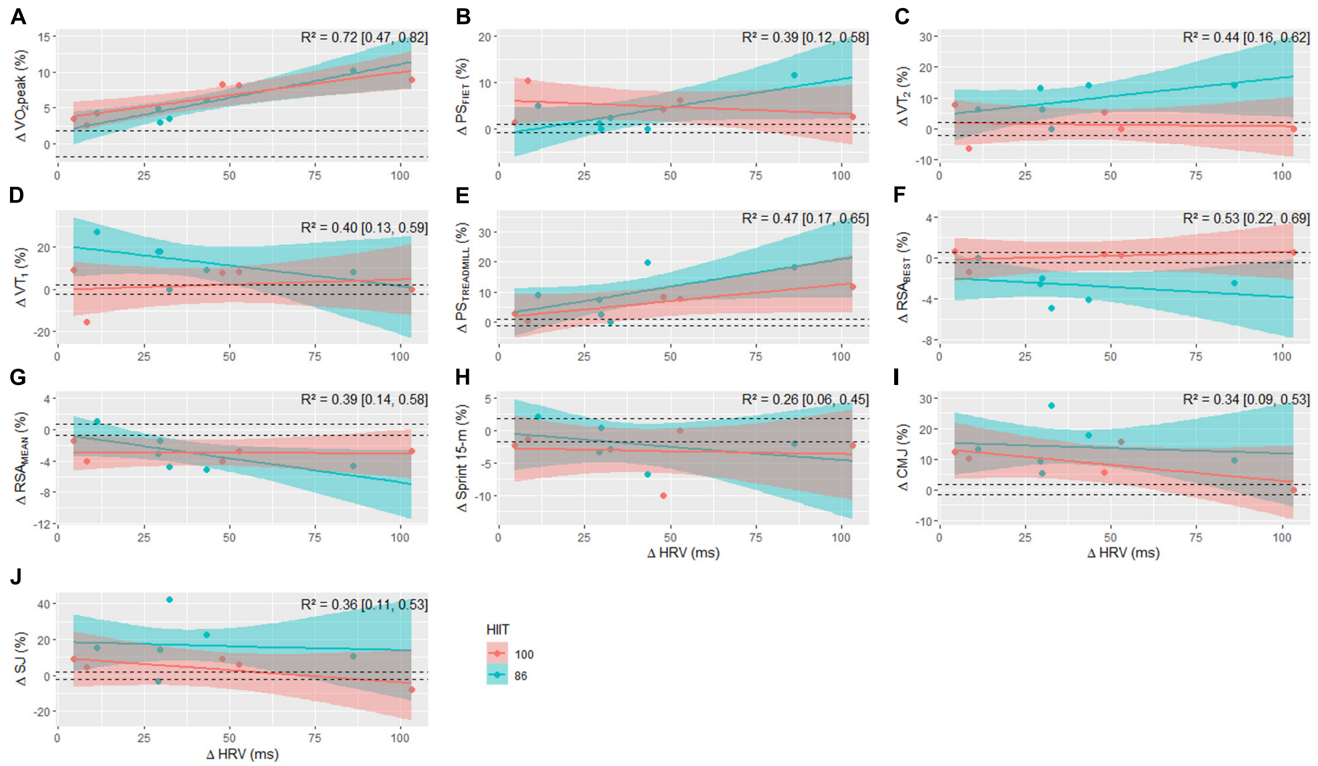

FIGURE 7 | Posterior regression medians with 90% credible intervals between pre-to-post changes in VO_2peak **(A)**, PS_{FIET} **(B)**, VT_2 **(C)**, VT_1 **(D)**, $PS_{TREADMILL}$ **(E)**, RSA_{BEST} **(F)**, RSA_{MEAN} **(G)**, Sprint 15-m **(H)**, CMJ **(I)**, and SJ **(J)** for each HIIT model with the pre-to-post change in HRV. R^2, Bayesian variance explained. Horizontal dashed lines are the lower and upper boundaries of the ROPE (i.e., 0.2× between subjects SD).

(VO_2peak, PS_{FIET}, $PS_{TREADMILL}$) and submaximal (VT_2 and VT_1) aerobic performance measures were considered low (25–28%) and moderate (45–59%), respectively. Contrary to what was observed in the anaerobic and jump performance measures, the dose-response relationship for aerobic performance outcomes did not show a distinct pattern between HIIT models (i.e., regression slopes in contrary directions). Of note, positive and negative/null relationships were observed between accumulated TL and changes in maximal (VO_2peak and $PS_{TREADMILL}$) and submaximal (VT_2 and VT_1) aerobic indices, respectively. Several studies have demonstrated a linear dose-response relationship between RPE-based TL and changes in aerobic performance indicators in team sports athletes (Oliveira et al., 2013; De Freitas et al., 2015; Clemente et al., 2019; Ellis et al., 2020; Nakamura et al., 2020). Interestingly, a recent study conducted by Ellis et al. (2020) also found a negative weak association between TL and changes at fixed lactate thresholds of 2 and 4 mmol/L (Bayesian $r = -0.17$ and -0.16, respectively) after 6 weeks of pre-season in a sample of male junior soccer players. Furthermore, in agreement with our data, a small positive relationship was verified between TL and $PS_{TREADMILL}$ changes (Bayesian $r = 0.37$) in the previously cited study (Ellis et al., 2020). It should be highlighted that the present study included 2 different shuttle-run HIIT types, so we chose to analyze the dose-response data with an interaction between TL and HIIT type. Thus, our Bayesian R^2 values consider both the relationship of the response to the TL and the HIIT model. Therefore, comparisons with the R^2 from other studies should be performed with caution to avoid misinterpretations, since they only used the TL as a covariate.

An interesting finding from our study to be highlighted was that similar improvements in the resting HRV were noticed after both HIIT models ($HIIT_{86}$ and $HIIT_{100}$) outlined here using PS_{FIET} as the reference speed to calibrate running distance. Although improved resting HRV after a period of futsal training has been previously documented in the literature (Oliveira et al., 2013; De Freitas et al., 2015; Nakamura et al., 2020), our data reinforce the effectiveness of shuttle run HIIT training models to induce positive adaptations in the cardiac autonomic function of young futsal players. This assumption was previously confirmed by Buchheit et al. (2008) who showed that HIIT models are preferable compared to repeated all-out sprint training methods, since its effects on cardiac autonomic function were significantly more pronounced in young handball players. The resting HRV, a non-invasive assessment of cardiac autonomic modulation, has also been constantly related to aerobic fitness indices and high-intensity running performance changes in team sport athletes (De Freitas et al., 2015; Esco et al., 2016; Nakamura et al., 2020). The present study showed a positive relationship between changes in resting HRV (i.e., rMSSD) and VO_2peak after the training period, suggesting that players in both HIIT models with greater increases in resting rMSSD demonstrated the largest increments in VO_2peak. Of interest, changes in resting HRV and HIIT types accounted for 72% of the inter-individual variance in VO_2peak changes in our sample. Another two studies performed with futsal players also showed that an enhanced vagal modulation (inferred by an increase in resting rMSSD value) was largely positively correlated (r = 0.62 and 0.64) with improvements in Yo-Yo IR1 performance (De Freitas et al., 2015; Nakamura et al., 2020). These explained variances (38–40%) are, at least in part, like those observed in our study for the ΔPS_{FIET} (39%) and $\Delta PS_{TREADMILL}$ (47%) (**Figure 7**). Collectively, the current and previous results indicate that resting rMSSD may be a simple and sensitive indicator to monitor changes in physical fitness during training.

One of the strengths of this study was to show how different HIIT models associated with other training components can influence the adaptive responses of players from the same futsal team. In this scenario, where few traditional HIIT sessions are planned by the team technical staff due to the matches schedule and the importance given to technical-tactical and strength/injury prevention sessions, the selection of training stimuli in HIIT sessions is key to maximizing subsequent performance adaptations. From a practical perspective, strength and conditioning specialists should consider spending more time in less intense shuttle run HIIT sessions with more COD than in more intense and shorter sessions with fewer directional changes.

The main limitation of the present study was the small sample size (n = 11). This can be justified by the low number of players who are part of a futsal squad (12–15 players). It would be extremely difficult to monitor more than one futsal team at one time. However, Bayesian analysis is better suited for making inferences on small sample sizes, as the MCMC methods used to produce posterior distributions do not depend on asymptotic behavior in the same way that traditional frequentist methods do (Kadane, 2015). Additionally, Bayesian inferences are more intuitive by posterior probability distributions of parameters (Kruschke, 2018). Nevertheless, a challenge in Bayesian statistics is the necessity to impose a prior knowledge in the parameters (i.e., prior distributions). In this way, we used non-informative default priors of the brms package (Bürkner, 2017). Therefore, the priors had little influence on the results (Gelman et al., 2008). Another point related to the analysis is that in team sports, such as futsal, there is no ROPE directly linked to performance. Thus, we used a ROPE of 20% between subjects SD [i.e., Cohen's d standardized mean differences transformed to percent units (Hopkins et al., 2009; Kruschke, 2018)] to infer about the substantiality of our results. Also, we acknowledge that the use of a single day HRV records at pre and post-training period is in disagreement with recent statements suggesting a minimum of 3 randomly selected HRV measurements per week (Plews et al., 2014; Nakamura et al., 2020). Another limitation of the present study is that no objective external load measure was used. A recent prior study suggested that decelerations, number of sprints, and distance covered should be considered to better discriminate the physical load of elite futsal players (Ribeiro et al., 2020). Future studies should consider using larger samples and adding more objective measures to run multiple linear regressions to explain the variations in determinant fitness variables.

CONCLUSION

This study showed that those players who underwent 8 shuttle run HIIT sessions at 86% PS_{FIET} had superior gains in aerobic, RSA, and neuromuscular performance measures than those who trained at 100% PS_{FIET} during a typical 10-week training period. In addition, the variance explained by the TL along with the HIIT type was clearly larger for the changes in RSA performance outcomes than that observed for aerobic and neuromuscular performance changes. Finally, monitoring resting HRV could be a suitable tool to track changes in VO_2peak, since temporal alterations in HRV are strongly related to VO_2peak changes.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by this study was approved by the local research ethics committee (n° 93777318.0.0000.0121). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FC participated in the design of the study, data collection, data organization, and drafted the manuscript. FB participated in the data organization, and performed the statistical analysis, interpretation, and discussion of results. LF and LB contributed with support of materials and data collection. AT participated in the design of the study and interpretation and discussion of results. RHN contributed to the design of the study and interpretation of results. LG contributed to the design of the study, interpretation and discussion of results, and coordination of project. All authors contributed to the writing and approved the final version.

FUNDING

This study was financed by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001.

ACKNOWLEDGMENTS

We would like to express our gratitude to all colleagues who contributed and to the subjects in this study and the team staff.

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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.

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ORIGINAL RESEARCH
published: 05 February 2021
doi: 10.3389/fpsyg.2021.610210

A Field-Based Approach to Determine Soft Tissue Injury Risk in Elite Futsal Using Novel Machine Learning Techniques

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Edited by:
Fábio Yuzo Nakamura, Instituto Universitário da Maia (ISMAI), Portugal

Reviewed by:
Antonio Garcia De Alcaraz Serrano, University of Almería, Spain
Paulo Roberto Pereira Santiago, University of São Paulo, Brazil

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 25 September 2020
Accepted: 14 January 2021
Published: 05 February 2021

Citation:
Ruiz-Pérez I, López-Valenciano A, Hernández-Sánchez S, Puerta-Callejón JM, De Ste Croix M, Sainz de Baranda P and Ayala F (2021) A Field-Based Approach to Determine Soft Tissue Injury Risk in Elite Futsal Using Novel Machine Learning Techniques. Front. Psychol. 12:610210. doi: 10.3389/fpsyg.2021.610210

Lower extremity non-contact soft tissue (LE-ST) injuries are prevalent in elite futsal. The purpose of this study was to develop robust screening models based on pre-season measures obtained from questionnaires and field-based tests to prospectively predict LE-ST injuries after having applied a range of supervised Machine Learning techniques. One hundred and thirty-nine elite futsal players underwent a pre-season screening evaluation that included individual characteristics; measures related to sleep quality, athlete burnout, psychological characteristics related to sport performance and self-reported perception of chronic ankle instability. A number of neuromuscular performance measures obtained through three field-based tests [isometric hip strength, dynamic postural control (Y-Balance) and lower extremity joints range of motion (ROM-Sport battery)] were also recorded. Injury incidence was monitored over one competitive season. There were 25 LE-ST injuries. Only those groups of measures from two of the field-based tests (ROM-Sport battery and Y-Balance), as independent data sets, were able to build robust models [area under the receiver operating characteristic curve (AUC) score ≥0.7] to identify elite futsal players at risk of sustaining a LE-ST injury. Unlike the measures obtained from the five questionnaires selected, the neuromuscular performance measures did build robust prediction models (AUC score ≥0.7). The inclusion in the same data set of the measures recorded from all the questionnaires and field-based tests did not result in models with significantly higher performance scores. The model generated by the UnderBagging technique with a cost-sensitive SMO as the base classifier and using only four ROM measures reported the best prediction performance scores (AUC = 0.767, true positive rate = 65.9% and true negative rate = 62%). The models developed might help coaches, physical trainers and medical practitioners in the decision-making process for injury prevention in futsal.

Keywords: injury prevention, modeling, screening, decision-making, algorithm, decision tree

INTRODUCTION

Lower extremity non-contact soft tissue (muscle, tendon, and ligament) (LE-ST) injuries are very common events in intermittent team sports such as soccer (López-Valenciano et al., 2019), futsal (Ruiz-Pérez et al., 2020), rugby (Williams et al., 2013), bat (i.e., cricket and softball) and stick (i.e., field hockey and lacrosse) sports (Panagodage Perera et al., 2018). It has been suggested that most of these LE-ST injuries occur when the resilience of soft tissue to injury is not enough to enable athletes to tolerate the loading patterns produced during the execution of high intensity dynamic tasks (e.g., cutting, sprinting, and landing) (Kalkhoven et al., 2020). Research has shown that LE-ST injuries can have major negative consequences on a team sport athlete's career (e.g., career termination) (Ristolainen et al., 2012) and can severely affect his/her well-being (Lohmander et al., 2007). Furthermore, when several injuries are sustained, team success (Eirale et al., 2013) and club finances can suffer (Fair and Champa, 2019; Eliakim et al., 2020). Given that the risk of sustaining a LE-ST injury can be mitigated when tailored measures are delivered, development of a validated screening model to profile injury risk would be a useful tool to help practitioners address this recurrent problem in team sports. Despite the substantive efforts made by the scientific community and sport practitioners, none of the currently available screening models (based on potential risk factors) designed to identify athletes at high risk of suffering a LE-ST injury, have adequate predictive properties (i.e., accuracy, sensitivity, and specificity) (Bahr, 2016).

Perhaps the lack of available valid screening models to predict LE-ST injuries could be attributed to the use of statistical techniques (e.g., traditional logistic regression) that have not been specifically designed to deal with class imbalance problems, such as the LE-ST injury phenomenon, in which the number of injured players (minority class) prospectively reported is always much lower than the non-injured players (majority class) (Galar et al., 2012; López et al., 2013; Fernández et al., 2017; Haixiang et al., 2017). Thus, in many scenarios including LE-ST injury, traditional screening models are often biased (for many reasons) toward the majority class (known as the "negative" class) and therefore there is a higher misclassification rate for the minority class instances (called the "positive" examples). Other issue with the current body of the literature is that the external validity of the screening models available may be limited because they are built and validated using the same date set (i.e., cohort of athletes). Apart from resulting in overly optimistic models' performance scores, this evaluation approach does not indicate the true ability of the models to predict injuries in different data sets or cohort of athletes, which may be very low and consequently, not acceptable for injury prediction purposes. This appears to be supported by the fact that the injury predictors identified by some prospective studies have not been replicated by others using similar designs and assessment methodologies but with different samples of athletes (Croisier et al., 2002, 2008; Arnason et al., 2004; Brockett et al., 2004; Hägglund et al., 2006; Fousekis et al., 2011; Dauty et al., 2016; Timmins et al., 2016; Van Dyk et al., 2016). These limitations have led some researchers to suggest that injury prediction may be a waste of time and resources (Bahr, 2016).

In Machine Learning and Data Mining environments, some methodologies (e.g., pre-processing, cost-sensitive learning, and ensemble techniques) have been specially designed to deal with complex (i.e., non-lineal interactions among features or factors), multifactorial and class imbalanced scenarios (Galar et al., 2012; López et al., 2013; Fernández et al., 2017; Haixiang et al., 2017). These contemporary methodologies along with the use of resampling methods to assess models' predictive power (i.e., cross-validation, bootstrap and leave-one-out) may overcome the limitations inherent to the current body of knowledge and enable the ability to build robust, interpretable, and generalizable models to predict LE-ST injuries. In fact, recent studies have used these contemporary methodologies and resampling methods as alternatives to the traditional logistic regression techniques to predict injuries in elite team sport athletes (Claudino et al., 2019). Unlike previous studies that used traditional logistic regression techniques to build prediction models (Fousekis et al., 2011; Zvijac et al., 2013; Opar et al., 2015; Hegedus et al., 2016; Van Dyk et al., 2016, 2017; Lee et al., 2018; O'Connor et al., 2020), most of these recent studies (Bartlett et al., 2017; Ge, 2017; Kautz et al., 2017; Ertelt et al., 2018; López-Valenciano et al., 2018; Rossi et al., 2018; Ayala et al., 2019), although not all (Thornton et al., 2017; Ruddy et al., 2018), have reported promising results [area under the receiver operator characteristics (AUC) scores > 0.700] to predict injuries.

However, one of the main limitations of most of these models built by the application of modern Machine Learning techniques lies in the fact that their use seems to be restricted to research settings (and not to applied environments) because sophisticated and expensive instruments (e.g., isokinetic dynamometers, force platforms, and GPS devices), qualified technicians and time-consuming testing procedures are required to collect such data. To the authors' knowledge, there is only one study that has built a robust screening model using Machine Learning techniques (extreme gradient boosting algorithms) with data from field-based tests. Rommers et al. (2020) built a model to predict injury in elite youth soccer players based on preseason anthropometric (stature, weight, and sitting height) and motor coordination and physical fitness (strength, flexibility, speed, agility, and endurance) measures obtained through field-based tests and reported an AUC score of 0.850.

If Machine Learning techniques could build "user friendly" models with adequate predictive properties and exclusively using data obtained from questionnaires and/or cost-effective, technically undemanding, and time-efficient field-based tests, then injury prediction would not be a waste of time and resource in applied settings. In case these techniques provided a trustworthy positive response, coaches, physical trainers, and medical practitioners may know whether any of the currently available questionnaires and field-based tests to predict injuries itself works and a hierarchical rank could be developed based on their individual predictive ability of those that showed reasonably high AUC, true positive (TP), and true negative (TN) scores. Furthermore, this knowledge might be used to analyze the cost-benefit (balance between the time required to assess a single player and the predictive ability of the measures recorded) of including measures in the screening sessions for injury prediction.

Therefore, the main purpose of this study was to develop robust screening models based on pre-season measures obtained from different questionnaires and field-based tests to prospectively predict LE-ST injuries after having applied supervise Machine Learning techniques in elite male and female futsal players.

MATERIALS AND METHODS

To conduct this study, guidelines for reporting prediction model and validation studies in Health Research [Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (the TRIPOD statement)] were followed (Collins et al., 2015). The TRIPOD checklist is presented in **Supplementary File 1**.

Participants

A convenience sample of 139 [72 (age: 22.5 ± 5.2 years, stature: 1.75 ± 0.7 m, body mass: 72.9 ± 6.9 kg) males and 67 (age: 22.4 ± 5.5 years, stature: 1.64 ± 0.5 m, body mass: 59.4 ± 5.1 kg) females] elite futsal players from 12 different teams [56 players (24 males and 32 females) from six club engaged in the First (top) National Spanish Futsal division and 83 players (48 males and 35 females) from six clubs engaged in the Second National Futsal division] completed this study. Elite futsal players were selected in this study because a recent published meta-analysis on injury epidemiology reported that this sport present high incidence rates of injuries (5.3 injuries per 1,000 hours of players exposure) (Ruiz-Pérez et al., 2020) and hence, urgent preventive measures are needed.

To be included in this study, all players had to be free of pain at the time of the study and currently involved in futsal-related activities. Players were excluded if: (a) they reported the presence of orthopedic problems that prevented the proper execution of one or more of the neuromuscular performance tests or (b) were transferred to another club and were not available for follow up testing at the end of 9 months. Only first injuries were used for any player sustaining multiple LE-ST injuries. The study was conducted at the end of the pre-season phase in 2015 (39 players from four teams), 2016 (44 players from four teams), 2017 (30 players from three teams), and 2018 (26 players from two teams) (September). Before any participation, experimental procedures and potential risks were fully explained to the players and coaches in verbal and written form and written informed consent was obtained from players. An Institutional Research Ethics committee approved the study protocol prior to data collection (DPS.FAR.01.14) conforming to the recommendations of the Declaration of Frontera.

Study Design

A prospective cohort design was used to address the purpose of this study. In particular, all LE-ST injuries accounted for within the 9 months following the initial testing session (in-season phase) were prospectively collected for all players.

Players underwent a pre-season evaluation of a number of personal, psychological, self-perceived chronic ankle instability and neuromuscular performance measurements, most of them considered potential sport-related injury risk factors. In each futsal team, the testing session was conducted at the end of the pre-season phase or beginning (within the first 3 weeks) of the in-season phase of the year. The testing session was divided into three different parts. The first part of the testing session was used to obtain information related to the participants' personal or individual characteristics. The second part was designed to assess psychological measures related to sleep quality, athlete burnout and psychological characteristics related to sport performance. The subjective perception of each player regarding his/her chronic ankle joints instability was also recorded in this second part. Finally, the third part of the session was used to assess a number of neuromuscular performance measures through three field-based tests. Each of the four testers who took part in this study had more than 6 years of experience in athletes' screening assessment.

Personal or Individual Measures

The *ad hoc* questionnaire designed by Olmedilla et al. (2011) was used to record personal or individual measures that have been defined as potential non-modifiable risk factors for sport injuries: player position (goalkeeper or outfield player), current level of play (First or Second division), dominant leg (defined as the player's kicking leg), demographic measures (sex, age, body mass, and stature) and the presence within the last season (yes or no) of LE-ST injuries with total time taken to resume full training and competition >8 days. **Supplementary File 2** displays a description of the personal risk factor recorded.

Psychological Risk Factors

The Spanish version of the Karolinska Sleep Diary (Cervelló et al., 2014) was used to measure the sleep quality of players. The Spanish version of the Athlete Burnout Questionnaire (Arce et al., 2012) was used to assess the three different dimensions that comprise athlete burnout: (a) physical/emotional exhaustion, (b) reduced sense of accomplishment and (c) sport devaluation. The Spanish version of the Psychological Characteristics Related to Sport Performance Questionnaire designed by Gimeno et al. (2012) was used to assess five different factors: (a) stress control, (b) influence of sport evaluation, (c) motivation, (d) mental skills, and (e) group / team cohesion. **Supplementary File 3** displays a description of the psychological risk factor recorded.

Self-Perceived Chronic Ankle Instability

The subjective perception of chronic ankle instability was measured using the Cumberland Ankle Instability Tool (CAIT). The final score was discretized into three categories of severity following the thresholds suggested by De Noronha et al. (2012): severe instability (<22 points), moderate instability (from 22 to 27 points) and minor or no instability (>27 points).

Neuromuscular Risk Factors

Prior to the neuromuscular risk factor assessment, all participants performed the dynamic warm-up designed by Taylor et al. (2009). The overall duration of the entire warm-up was approximately 15–20 min. The assessment of the neuromuscular risk factors was carried out 3–5 min after the dynamic warm-up.

Neuromuscular capability was determined from two different performance field-based tests: (1) isometric hip abduction and adduction strength test (Thorborg et al., 2009) and (2) Y-Balance test (dynamic postural control) (Shaffer et al., 2013). The ROM-Sport field-based battery was also carried out to assess players' lower extremity joints range of motion (Cejudo et al., 2014).

For a matter of space, the testing maneuvers are not described below, and the reader is to refer to their original sources. Furthermore, **Supplementary Files 4–6** display a description of the three field-based testing maneuvers carried and the measures recorded from each of them.

The order of the tests was consistent for all participants and was established with the intention of minimizing any possible negative influence among variables. A 5 min rest interval was given between consecutive testing maneuvers.

Injury Surveillance

For the purpose of this study, an injury was defined as any non-contact, soft tissue (muscle, tendon, and ligament) injury sustained by a player during a training session or competition which resulted in a player being unable to take a full part in future football training or match play (Bahr et al., 2020).

These injuries were confirmed by team doctors. Players were considered injured until the club medical staff (medical doctor or physiotherapist) allowed for full participation in training and availability for match selection. Only thigh muscle (hamstrings, quadriceps, and adductors) and knee and ankle ligament injuries were considered for the analysis as these injuries are more likely to be preventable and influenced by the investigated variables.

The team medical staff of each club recorded LE-ST injuries on an injury form that was sent to the study group each month. For all LE-ST injuries that satisfied the inclusion criteria, team medical staff provided the following details to investigators: thigh muscle (hamstrings, quadriceps, and adductors), knee or ankle ligament, leg injured (dominant/non-dominant), injury severity based on lay-off time from futsal [slight/minimal (0–3 days), mild (4–7 days), moderate (8–28 days), and severe (>28 days)], date of injury, moment (training or match), whether it was a recurrence (defined as a soft tissue injury that occurred in the same extremity and during the same season as the initial injury) and total time taken to resume full training and competition. At the conclusion of the 9 month follow-up period, all data from the individual clubs were collated into a central database, and discrepancies were identified and followed up at the different clubs to be resolved. Some discrepancies among medical staff teams were found to diagnose minimal LE-ST injuries and to record their total time lost. To resolve these inconsistencies in the injury surveillance process (risk of misclassification of the players), only ST-LE injuries showing a time lost of >8 days (moderate to severe) were selected for the subsequent statistical analysis.

Statistical Analysis

After having completed an exhaustive data cleaning process [detected anomalies or errors were removed (16 cases) and missing data (2.3%) were replaced by the mean value of the corresponding variable according to the sex (male or female) of the players] we had an imbalanced (showing an imbalance ratio of 0.22) and a high-dimensional data set comprising of 72 male and 67 female futsal players (instances) and 66 potential risk factors (features). In this study, an anomalies or error was defined as a score or value that could not be classified as real or true because of the consequence of a human error or a machine failure. An example of an error was a hip adductor PT value of 1,500 N because the measurement range of the handheld dynamometer used was from 0 to 1,335 N.

Prior to analysis, continuous data were discretized as this can improve the performance of some classifiers (Hacibeyoglu et al., 2011). Continuous variables were discretized using the unsupervised discretization algorithm available in Weka repository (Waikato Environment for Knowledge Analysis, version 3.8.3), selecting the option "optimize the number of equal-width bins" (a maximum of 10 bins were allowed per variable).

Afterward, eleven data sets were built. In particular, five data sets were built using the personal [data set (DS) 1—personal variables], psychological (DS 2—sleep quality, DS 3—athlete burnout and DS 4—psychological characteristics related to sport performance) and self-perceived (DS 5—player's self-perceived chronic ankle joint stability) measures recorded from the questionnaires selected in this study. Likewise, three data sets were also built using the data from each of the three field-based tests carried out (DS 6—ROM-Sport battery, DS 7—isometric hip abduction and adduction strength test and DS 8—Y-Balance test). Finally, three extra data sets were built, one that grouped all the measures obtained from the questionnaires (DS 9—questionnaire-based personal, psychological, and self-perceived measures), another one that included all the neuromuscular performance measures recorded from the field-based tests (DS 10—neuromuscular performance measures from field-based tests) and finally one that contained all measures recorded (DS 11—global).

The taxonomy for learning with imbalanced data sets proposed by Galar et al. (2012) and López et al. (2013) was applied in each data set. Furthermore, this taxonomy was implemented with the approach recently proposed by Elkarami et al. (2016) because of the good results (in term of predictive performances) showed to handle imbalanced data sets (**Supplementary File 7**).

Four classifiers based on different paradigms, namely decision trees with C4.5 (Quinlan, 1996) and ADTree (Freund and Mason, 1999), Support Vector Machines with SMO (Gove and Faytong, 2012) and the well-known k-Nearest Neighbor (KNN) (Steinbach and Tan, 2009) as an Instance-Based Learning approach were selected. The configuration of each base classifier was optimized through the use of the metaclassifier MultiSearch.

Due to the high dimensionality of the DS 10-neuromuscular measures from field-based tests (47 variables) and DS 11-Global (66 variables), before running the algorithms included in the taxonomy just described, a feature selection process was carried out. In particular, we used the metaclassifier "attribute selected classifier" (with GreedyStepwise as search technique) available in Weka's repository to address the feature selection process.

To evaluate the performance of the algorithms, the fivefold stratified cross-validation technique was used (Refaeilzadeh et al., 2009). The fivefold stratified cross validation was repeated a hundred times and results were averaged over the runs to obtain a more reliable estimate for the generalization ability.

The AUC and F-score were used as measures of a classifier's performance (Altman and Bland, 1994; Zou et al., 2016). Only those algorithms whose performance scores (AUC) were higher than 0.70 were considered as acceptable for the purposes of this study and included in the intra and inter dataset comparisons analyses. Furthermore, two extra measures from the confusion matrix were also used as evaluation criteria: (a) true positive (TP) rate also called sensitivity or recall and (b) true negative (TN) rate or specificity.

In order to compare the performance of the algorithms ran in each data set (intra data set comparisons) and whose AUC scores were >0.70, the F score was selected as criterion measure. These comparisons were conducted using separate Bayesian inference analyses (Rouder et al., 2012; Lee and Wagenmakers, 2014; Wagenmakers et al., 2018). In those data sets in which (at least) a strong evidence for rejecting null hypothesis (H_0 = no differences across algorithms' performance scores) was found (Bayesian factor [BF_{10}] > 10), a *post hoc* procedure was carried out to identify the best performing model. In the cases in which either there would not be a strong evidence for rejecting H_0 or a group of algorithms showed the highest F-score results [without any relevant difference ($BF_{10} < 10$) among then], the best-performing algorithm for this dataset would be the one that showed the highest F-scores.

Finally, the best performing algorithm of each of the data sets were compared (inter dataset comparisons) using the same statistical approach in order to know which questionnaire, field-based test, or combination showed the best ability to predict moderate LE-ST injuries in elite male and female futsal players.

RESULTS

Soft-Tissue Lower Extremity Injuries Epidemiology

There were 31 (16 in males and 15 in females) soft tissue injuries over the follow-up period, 17 (54.8%) of which corresponded to thigh muscles (seven hamstrings, four quadriceps, and six adductors) injuries, eight (25.8%) to knee ligament, and six (19.3%) to ankle ligament. Injury distribution between the legs was 74.1% dominant leg and 25.9% non-dominant leg. A total of 13 injures occurred during training and 18 during competition. In terms of severity, most injures were categorized as moderate ($n = 23$), whereas only eight cases were considered severe injuries (five anterior cruciate ligament injuries). Five players sustained multiple soft tissue non-contact lower extremity injuries during the observation period, so their first injury was used as the index injury in the analyses. Consequently, 25 soft-tissue injuries were finally used to develop the prediction models.

Prediction Models for Soft Tissue Lower Extremity Injuries

All data sets are publicly available on https://data.mendeley.com/datasets/s7fs9k3nby/1. As all the algorithms selected in this study can be found in the Weka experimenter, only the scheme (and not the full code) of algorithms selected in each data set are displayed in **Supplementary File 19** in order to allow practitioners to replicate our analyses and to use the models generated with their futsal players.

Intra-Data Set Comparisons

As displayed in the **Supplementary Files 8–18**, only four (DS 6—lower extremity joint ranges of motion, DS 8—dynamic postural control, DS 10—neuromuscular performance measures from field-based tests and DS 11—Global) out of 11 data sets resulted in the ability of the classification algorithms to build prediction models for LE-ST injuries with AUC scores ≥ 0.7.

For the DS 6 - lower extremity joint ranges of motion, a total of 23 learning algorithms showed AUC scores ≥ 0.7. The Bayesian inference analysis carried out with these 23 algorithms (Bayesian ANOVA) reported the presence of relevant differences [$BF_{10} > 100$ (extreme evidence for supporting H_1)] among their prediction performance scores. The subsequent *post hoc* analysis identified a sub-group of four algorithms whose F-scores were similar among them (F-scores ranging from 0.422 to 0.450) and also statistically higher ($BF_{10} > 10$) than the rest (**Table 1**). Among these four algorithms, the one that showed the highest F-score was the CS-Classifier technique with ADTree as base classifier (**Figure 1**).

For its part, the DS 8—dynamic postural control only allowed to the class-balanced ensemble CS-UBAG with C4.5

TABLE 1 | Features selected (displayed for order of importance) after having applied the classify subset evaluator filter to the data sets (DS) 10 and 11.

Neuromuscular measures from field-based tests (DS—10)
ROM-HF_{KE} (dominant leg)
ROM-$AKDF_{KE}$ (dominant leg)
ROM- $AKDF_{KF}$ (dominant leg)
ROM-BIL- HABD
Global (DS—11)
ROM-HF_{KE} (dominant leg)
ROM-$AKDF_{KE}$ (dominant leg)
ROM- $AKDF_{KF}$ (dominant leg)
ROM-BIL-HABD
Self-perceived chronic ankle instability (non-dominant leg)
History of lower extremity soft tissue injury last season

ROM, range of motion; HF_{KE}, hip flexion with the knee extended; HABD, hip abduction at 90° of hip flexion; $AKDF_{KE}$, ankle dorsi-flexion with the knee extended; $AKDF_{KF}$, ankle dorsi-flexion with the knee flexed; BIL, bilateral ratio.

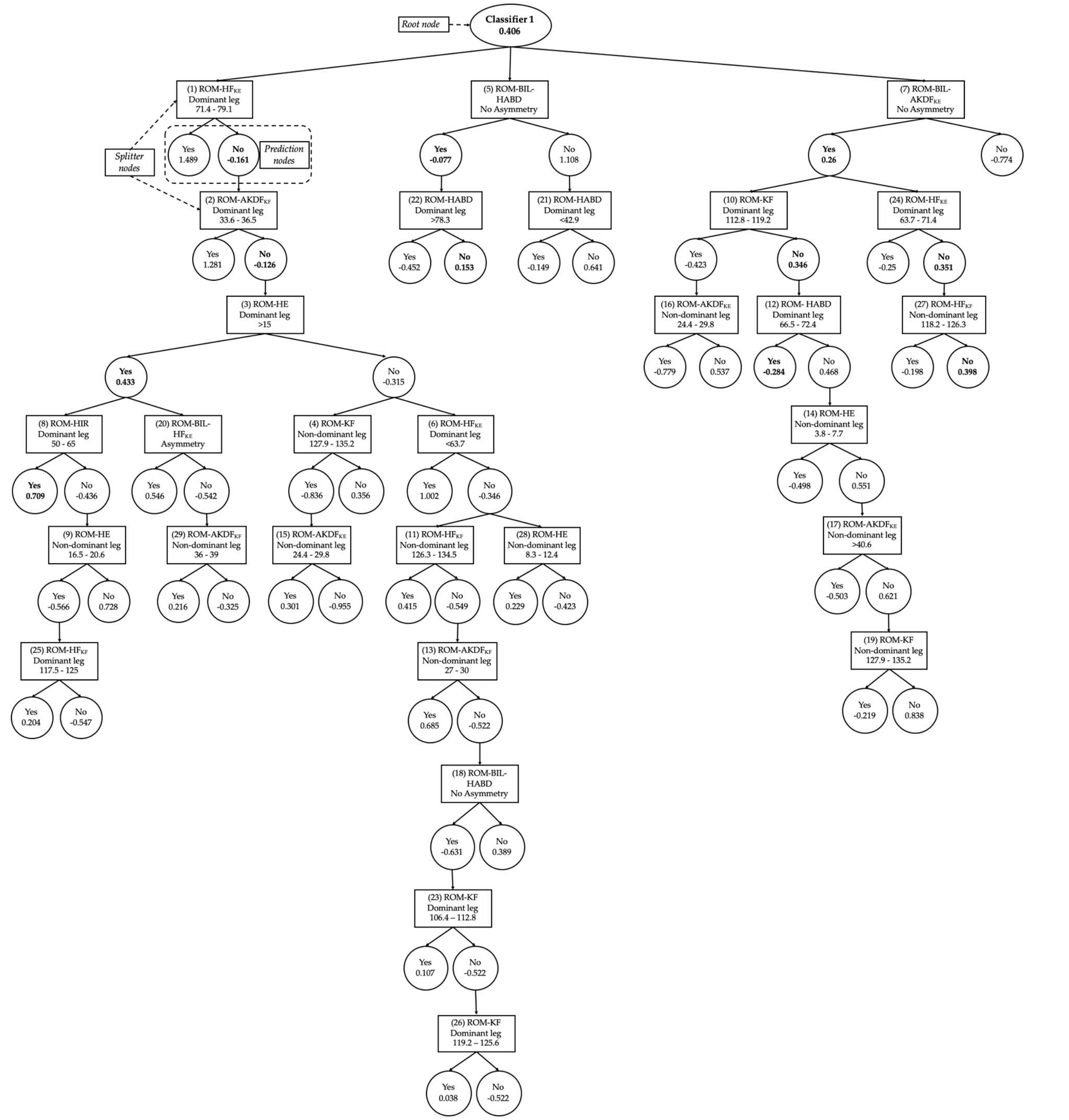

FIGURE 1 | Graphical representation of the first classifier of the DS 6 (lower extremity joint ranges of motion). Prediction nodes are represented by ellipses and splitter nodes by rectangles. Each splitter node is associated with a real valued number indicating the rule condition, meaning: If the feature represented by the node satisfies the condition value, the prediction path will go through the left child node; otherwise, the path will go through the right child node. The numbers before the feature names in the prediction nodes indicate the order in which the different base rules were discovered. This ordering can to some extent indicate the relative importance of the base rules. The final classification score produced by the tree is found by summing the values from all the prediction nodes reached by the instance, with the root node being the precondition of the classifier. If the summed score is greater than zero, the instance is classified as true (low risk of LE-ST injury).

as base classifier building a model with AUC scores $\geq$ 0.7 (AUC = 0.701 $\pm$ 0.112). In this sense, this model is comprised for 100 different C4.5 decision trees (**Figure 2** shows an example of one of these C4.5 decision trees, the rest can be got upon request to the authors).

The feature selection process carried out in the DS 10—neuromuscular measures from field-based tests identified a subset of four ROM measures as the most relevant (considering the individual predictive ability of each feature along with the degree of redundancy among them) on which was subsequently

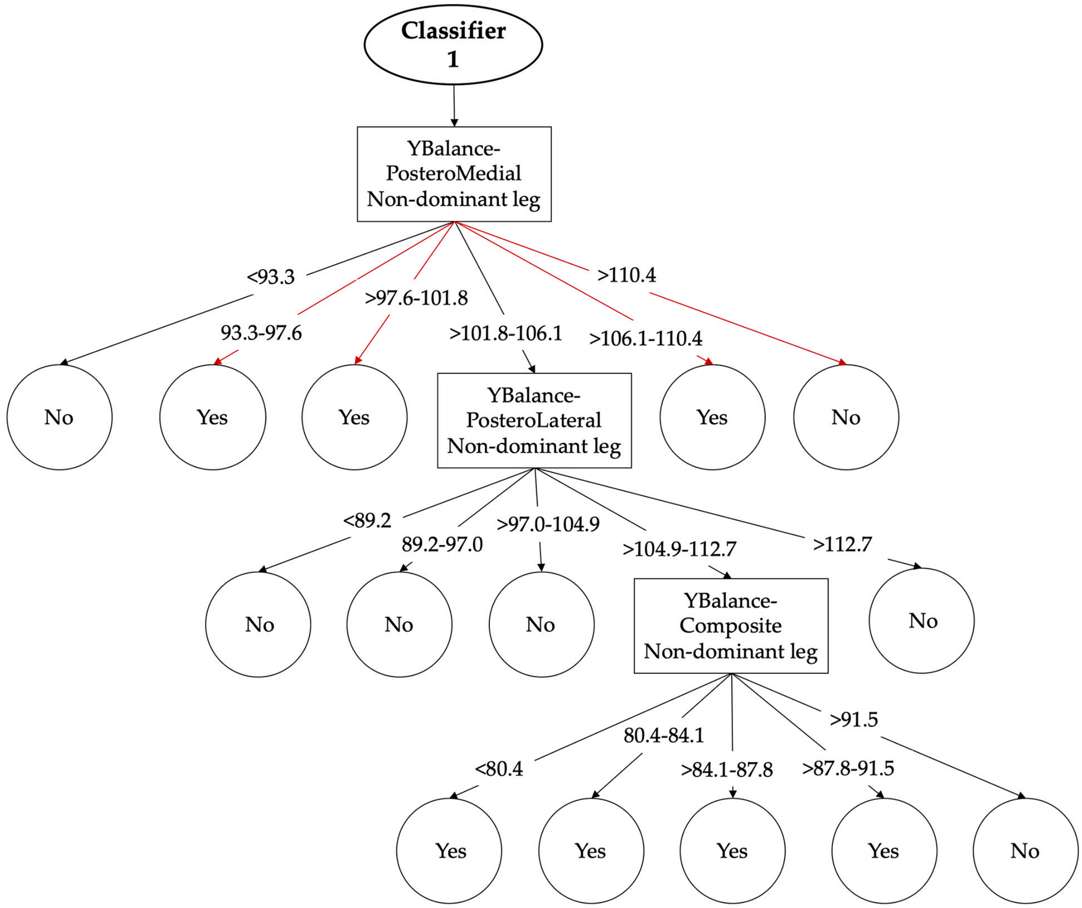

FIGURE 2 | Graphical representation of the first classifier of the DS 8 (dynamic postural control). The arrows show the single pathway (transverse to the tree) through the classifier that should be followed according to participant's scores in order to achieve a dichotomic output [high (Yes) or low (No) risk of LE-ST injury].

applied the taxonomy of learning algorithms described in the "Materials and Methods" section. Thus, a total of 66 algorithms built (using this subset of features) prediction models with AUC scores ≥0.7. The Bayesian analysis conducted with these 66 algorithms documented the existence of relevant differences [with an extreme degree of evidence ($BF_{10} > 100$)] among their predictive ability scores. The subsequent *post hoc* analysis reported that a group of three algorithms showed similar F-scores among them (ranging from 0.458 to 0.474) but significantly higher than the rest. Therefore, the selection of the best performing algorithm of this DS 10 was based on the highest F-score. Thus, the algorithm CS-UBAG with SMO as base classifier was the one that showed the highest F-score (0.474 ± 0.111) and hence, it was selected for the inter data set comparisons. **Figure 3** displays an example of the 100 predictors than this prediction model is comprised (the rest can be got upon request to the authors).

The DS 11, that comprised of the 66 personal ($n = 8$), psychological ($n = 9$), self-perceived chronic ankle instability ($n = 2$) and neuromuscular performance (47) features was reduced to a subset of six features by the feature selection metaclassifier selected, from which four were ROM measures, one was a self-perceived chronic ankle instability measure and the last one belonged to the group of personal measures (**Table 2**). This sub-set of features allowed 59 algorithms building prediction models showing AUC scores ≥0.7. Finally, and it is showed in the **Table 1**, the Bayesian inference and the subsequent *post hoc* analyses identified the class-balanced ensemble CS-UBAG with C4.5 as base classifier as the best-performing algorithm (AUC = 0.749 ± 0.105, TP rate = 75.5% ± 23.6, TN rate = 62.7 ± 11.5, F-score = 0.436 ± 0.122). An example of the 100 C4.5 decision trees that comprised this model is presented in **Figure 4**.

Inter-Data Set Comparisons

The inter data set comparison analysis carried out with the best-performing algorithms of the DS 6 [CS-Classifier (ADTree)], 8 [CS-UBAG (C4.5)], 10 [CS-UBAG (SMO)] and 11 [CS-UBAG (C4.5)] showed that the algorithm of the DS 8 obtained significantly lower F-scores than the other three algorithms ($BF_{10} > 100$). However, there were no statistically differences among the algorithms from the DS 6, 10, and 11. Among these three algorithms, the one from the DS 10 demonstrated the

Classifier 1 of the field-based tests model (CS-UBAG [SMO])

Equation → $f(x) = (w_1x_1 + ... + w_dx_d) + b = \langle w,x \rangle + b$

1. (0.999 * [normalized] ROM-HF$_{KE}$ dominant leg [< 63.7]) +
2. (-1.0003 * [normalized] ROM-HF$_{KE}$ dominant leg [63.7 - 71.4]) +
3. (1.0007 * [normalized] ROM-HF$_{KE}$ dominant leg [71.4 – 79.1]) +
4. (-0.9994 * [normalized] ROM-HF$_{KE}$ dominant leg [>79.1]) +
5. (-0.002 * [normalized] ROM-AKDF$_{KE}$ dominant leg [>44.5]) +
6. (1.3336 * [normalized] ROM-AKDF$_{KF}$ dominant leg [< 30]) +
7. (-0.6663 * [normalized] ROM-AKDF$_{KF}$ dominant leg [30 – 40]) +
8. (-0.6673 * [normalized] ROM-AKDF$_{KE}$ dominant leg [>40]) +
9. (1.9992 * [normalized] ROM-BIL- HABD [Asymmetry]) +

   0.6668 (b)

Classification:

- Negative score = Yes
- Positive score = No

Normalized: scale from 0 to 1, ROM: range of motion, HF: hip flexion, KE: knee extension, KF: knee flexion, BIL: bilateral ratio, AKDF: ankle dorsiflexion, HABD: hip abduction.

FIGURE 3 | Description of the first classifier of the DS 10 (field-based tests).

highest F-score and was considered as the "winning model" (**Table 2**). Models from DS 8, 10, and 11 are comprised by 100 classifiers. In term of practical applications, each classifier has a vote or decision [yes (high risk of LE-ST injury) or no (lower risk of LE-ST injury)], and the final decision regarding whether or not a player might suffer an injury is based on the combination of the votes of each individual classifier to each class (yes or no).

TABLE 2 | Best-performing sub-set of algorithms for those data sets (DS) that allowed building prediction models with AUC scores ≥0.7.

Technique	Performance measures			
	AUC	TP rate (%)	TN rate (%)	F-score
		Lower extremity joint ranges of motion (DS—6)		
ADTree	0.754 ± 0.122	35.8 ± 21.6	93.4 ± 6.3	0.433 ± 0.195
ROS (ADTree)	0.745 ± 0.126	46.1 ± 23.5	87.4 ± 8.3	0.442 ± 0.188
CS-Classifier (ADTree)	**0.757 ± 0.124**	**44.7 ± 23.2**	**89.1 ± 8.4**	**0.450 ± 0.184**
CS-UBAG (ADTree)	0.737 ± 0.106	48.3 ± 21.5	83.0 ± 8.1	0.422 ± 0.161
		Dynamic postural control (DS—8)		
CS-UBAG (C4.5)	**0.701 ± 0.114**	**64.9 ± 21.1**	**63.3 ± 10.4**	**0.388 ± 0.109**
		Neuromuscular measures from field-based tests (DS—10)		
CS-OBAG (SMO)	0.760 ± 0.103	83.3 ± 22.9	62.9 ± 10.0	0.469 ± 0.115
CS-UBAG (C4.5)	0.748 ± 0.089	87.6 ± 20.3	57.2 ± 10.7	0.458 ± 0.100
CS-UBAG (SMO)	**0.767 ± 0.096**	**85.1 ± 21.4**	**62.1 ± 9.8**	**0.474 ± 0.111**
		Global (DS—11)		
OBAG (SMO)	0.742 ± 0.125	51.3 ± 25.5	79.5 ± 9.6	0.410 ± 0.179
UBAG (SMO)	0.737 ± 0.121	54.7 ± 25.6	76.3 ± 10.2	0.410 ± 0.171
CS-OBAG (C4.5)	0.751 ± 0.107	60.9 ± 28.2	73.2 ± 10.6	0.418 ± 0.163
CS-OBAG (SMO)	0.747 ± 0.121	65.1 ± 27.9	70.1 ± 11.3	0.423 ± 0.151
CS-UBAG (C4.5)	**0.749 ± 0.105**	**75.5 ± 23.6**	**62.7 ± 11.5**	**0.436 ± 0.122**
CS-UBAG (ADTree)	0.741 ± 0.119	62.0 ± 27.3	72.0 ± 10.4	0.419 ± 0.161
CS-UBAG (SMO)	0.747 ± 0.116	70.8 ± 26.1	66.5 ± 10.9	0.433 ± 0.137
CS-UBAG (IBK)	0.722 ± 0.124	71.8 ± 23.9	61.6 ± 12.3	0.413 ± 0.122
CS-SBAG (C4.5)	0.755 ± 0.115	55.7 ± 28.2	76.2 ± 11.0	0.409 ± 0.175
CS-SBAG (SMO)	0.750 ± 0.121	58.4 ± 27.2	74.7 ± 11.1	0.416 ± 0.164

Highlighted in bold are the algorithms selected in each DS for the posterior inter-group comparative analysis.
AUC, area under the ROC curve; TP rate, true positive rate; TN rate, true negative rate.

DISCUSSION

The main findings of this study indicate that only those groups of measures from two of the field-based tests [ROM-Sport battery (AUC = 0.751 ± 0.124) and Y-Balance (AUC = 0.701 ± 0.114)], as independent data sets, can build robust models (AUC ≥ 0.7) to identify elite futsal players at risk of sustaining a LE-ST injury. One of the possible reasons why only the lower extremity ROM and dynamic postural control measures can separately build robust prediction models may be related to the fact that they play a significant role in the hazardous lower extremity movement patterns performed by futsal players. In particular the execution of numerous weight-bearing high intensity locomotive actions (e.g., cutting, landing, and sprinting) that may produce excessive dynamic valgus at the knee with limited hip and knee flexion ROMs, which have been identified as primary and modifiable LE-ST injury patterns (Robinson and Gribble, 2008; Thorpe et al., 2008; Lockie et al., 2013; Ambegaonkar et al., 2014; Booysen et al., 2015; Overmoyer and Reiser, 2015). The fact that the best-performing model built with the ROM data set (DS 6) showed a significantly higher prediction performance [and also less decision trees (1 vs. 100)] than its counterpart model built with the dynamic postural control data set (DS 7) (F-score = 0.450 vs. 0.388) may be due to the fact that the scores obtained thorough the Y-Balance test are widely influenced by hip and knee flexion and the ankle dorsiflexion ROM measures in the sagittal plane and to less extend by dynamic core stability (in the frontal plane) and isokinetic knee flexion strength measures (Ruiz-Pérez et al., 2019). Thus, the dynamic postural control measures obtained from the Y-Balance test might have allowed the construction of a model with an acceptable prediction ability mainly due to the influence of whole lower limb posterior kinetic chain ROMs in the distances reached. This hypothesis may also be supported by the fact that the feature selection process carried out in the data set in which all the neuromuscular performance measures were grouped (DS 10) and also in the data set that contained all the measures recorded in this study (DS 11) did not consider any of the dynamic postural control measures in contrast to the hip flexion and ankle dorsiflexion ROM measures that were considered LE-ST injury predictors.

Previous studies have explored the individual predictive ability of some (but not many) field-based tests [e.g., Y-Balance (Butler et al., 2013), leg squat (O'Connor et al., 2020), side plank (Hegedus et al., 2016), and drop jump (Myer et al., 2010, 2011)] to identify athletes from intermittent team sports at high risk of LE-ST injury using traditional logistic regression techniques. Most

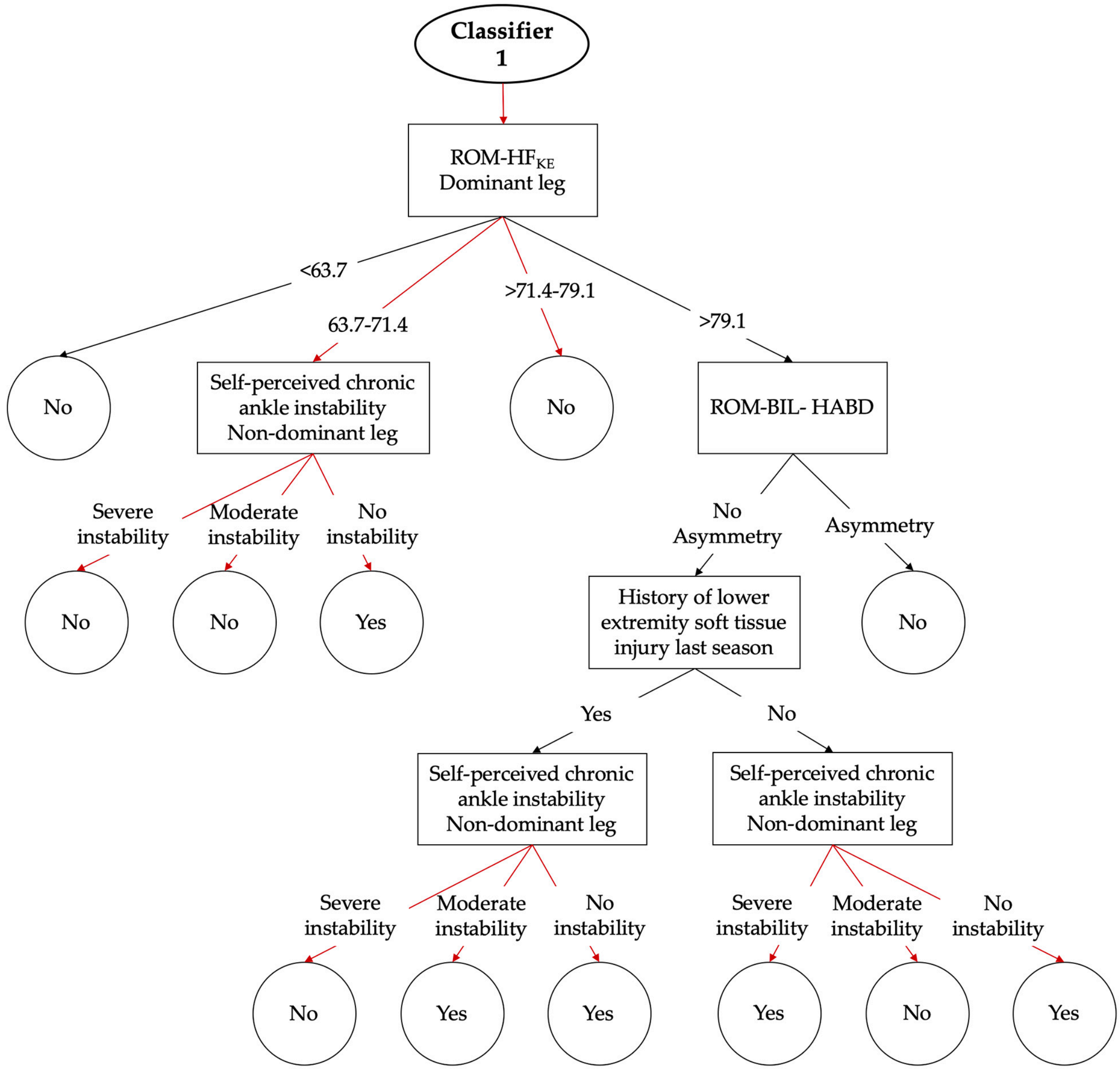

FIGURE 4 | Graphical representation of the first classifier of the DS 11 (global). The arrows show the single pathway (transverse to the tree) through the classifier that should be followed according to participant's scores in order to achieve a dichotomic output [high (Yes) or low (No) risk of LE-ST injury].

of these studies have reported models exhibiting high sensitivity values (TN rates) but very low specificity values (TP rates) and hence, cannot be used for injury prediction. For example, O'Connor et al. (2020) examined whether a standardized visual assessment of squatting technique and core stability can predict lower extremity injuries in a large sample of collegiate Gaelic players (n = 627). The logistic regression-based model generated revealed that while the TP rate was moderate to high (76%) the TN rate was low (44%). This circumstance reflects one of the main limitations inherent in traditional regression techniques, that is to say, they do not deal well with imbalanced data sets [their models usually are biased toward the majority class (true negative rates) to optimize the percentage of well-classified instances] (Galar et al., 2012). Furthermore, the validation technique applied to the models generated in these studies may not be exigent enough to ensure that the phenomenon of over-fitting was minimized as the models were validated using the data from the population with whom the prediction equations were generated (Bahr, 2016; Jovanovic, 2017).

Due to their high cost (approximately 250€ per unit) currently available GPS systems may not be considered as accessible tools for most practitioners that work in applied sport settings, however, it should be noted that prediction models to identify team sport athletes (mainly soccer and rugby players) at risk of sustaining a LE-ST injury based exclusively on external training workload measures and built using learning algorithms are available (Bartlett et al., 2017; Thornton et al., 2017; Rossi et al., 2018). However, only the model reported by Rossi et al. (2018) has shown AUC scores ≥0.7 after 16 weeks of data collection (AUC = 0.760). The predictive ability of the model built by Rossi et al. (2018) is very similar to the predictive ability shown in our best-performing prediction model built using only lower extremity ROM measures (AUC = 0.757). Nevertheless, our prediction model based on ROM measures has a higher external validity for practitioners in applied environments due to two main aspects. Firstly, the low cost of the materials needed to conduct the assessment maneuvers (inclinometer with a telescopic arm = 200€, lumbar protection support = 50€). Secondly, our model was developed and validated using ROM measures from 139 elite futsal players from 12 different teams, whereas Rossi et al. (2018) only assessed the external training workload of 26 elite soccer players all from the same team. Consequently, the model displayed by Rossi et al. (2018) can only be used by the medical and performance staff of the team in which the external workload measures were collected due (among other factors) to the high inter-team differences in training and competitive calendars, drills prescribed in training sessions and tactical systems adopted throughout match play.

The results of this study also reported that the combination in the same data set (DS 9) of all the measures obtained from the five questionnaires selected did not permit classification algorithms to build prediction models with acceptable performance scores (AUC scores ranged from 0.443 to 0.558). Previous studies have documented the existence of significant associations between some personal characteristics [e.g., age (Arnason et al., 2004; Hägglund et al., 2006; Dauty et al., 2016) and recent history of injury (Brockett et al., 2004; Hägglund et al., 2006; López-Valenciano et al., 2018; Ayala et al., 2019)], psychological constructs [e.g., physical/emotional exhaustion, reduce sense of accomplishment, sports devaluation (Cresswell and Eklund, 2006; Moen et al., 2016)] and self-perceived chronic ankle instability (Hiller et al., 2006, 2011), sleep quality (López-Valenciano et al., 2018; Palucci Vieira et al., 2020) measures, and LE-ST injury. However, it may be possible that the magnitude of these associations between the questionnaire-based measures and LE-ST injury, neither individually nor collectively, are strong enough to build robust models with the aim of identifying elite futsal players at risk of LE-ST injury. On the contrary, the grouping in the same data set (DS 10) of all the neuromuscular performance measures obtained from the three field-based tests did permit prediction models to be built with moderate performance scores (AUC $\geq$ 0.7). The feature selection technique applied to this data set with the aim of reducing its dimensionality (46 features) through deleting redundant and not relevant measures (considered as noise) only selected four ROM measures, with whom the CS-UBAG method with SMO as base classifier built a prediction model with AUC and F-scores of 0.767 and 0.474, respectively. This model reported the highest performance scores, together with the fact that only two hip and two ankle ROM measures are needed to run the screen in a single player making it appropriate for applied scenarios. Finally, the inclusion in the same data set (DS 11) of all the eight groups of measures obtained from the five questionnaires and three field-based tests did not result in models with significantly higher performance scores and hence, the null hypothesis was rejected.

The prediction properties of the "model of best fit" of the current study were lower than that reported by the only other study that has used Machine Learning techniques to develop a screening model based on field-based measures (AUC = 0.767 vs. 0.850, TP rate = 85 vs. 85%, TN rate = 62 vs. 85%) (Rommers et al., 2020). One of the potential reasons that may explain this difference in models' predictive performance in favor of Rommers et al.'s 2020 model can be attribute to its higher sample size (734 elite young soccer players vs. 139 elite adult futsal players) and the less rigorous resampling technique applied in its validation process [hold out with 20% of the sample (test data set) vs. fivefolds stratified cross validation]. Although the predictive properties of our model are lower than Rommers et al.'s 2020 model (but they are acceptable for an injury prediction standpoint), it should be highlighted that only four ROM measures and 5 min are needed to run the screen in a single player, unlike Rommers et al.'s 2020 model that requires 20 measures obtained from a questionnaire and five different field-based tests, which can take longer than 45 min to collect all of them in a single player.

The current study has a number of limitations that must be acknowledged. The first potential limitation of the current study is the population used. The sport background of participants was elite futsal and the generalizability to other sport modalities and level of play cannot be ascertained. Although all the measures recorded during the screening session are purported as LE-ST injury risk factors, there are a number of other measures from different questionnaires and field-based tests not included in this study (due to time constraints) which have been associated with LE-ST injury (e.g., back extensor and flexor endurance measures, bilateral leg strength asymmetries, relative leg stiffness and reactive strength index) and that may have improved the ability to predict LE-ST injuries in this cohort of athletes. Neither situational (e.g., pressing and tackling, regaining balance after kicking, side-stepping, and landing from a jump) nor movement (e.g., excessive dynamic knee valgus motion at the knee, limited hip, and knee flexion angles) patterns for those futsal players who suffered a LE-ST injury were recorded for this study due to technical reasons (i.e., training sessions and matches were not recorded and hence, a systematic biomechanical/kinematic video analysis on injury patterns was not possible to be conducted). Although the main findings of this study may help identify futsal players at high risk of LE-ST injury, having included information regarding situational and movement injury patterns in the models might have not only increase their predictive performance scores but shed light on why and how LE-ST injuries occur in futsal players. Despite the fact that the number of both futsal players assessed (n = 139) and LE-ST injuries recorded (n = 25) was large enough to build robust prediction models, the inclusion of more instances in the learning processes of the models may have improved their performance scores. Finally, out of the 8^8 possible combinations of measures that could have been analyzed with the data from the five questionnaires and three field-based tests, only three of them were explored, from both a time perspective and based on those that would be most interesting from a practitioner perspective. Therefore, it is unknown if other combinations of measures, different from the ones analyzed in this study, may have provided prediction models with higher AUC scores.

CONCLUSION

In conclusion, thanks to the application of novel machine learning techniques, the current study has developed four screening models based on field-based measures (mainly ROM and dynamic postural control features) that showed moderate accuracy (AUC scores ranged from 0.701 to 0.767, determined all through the exigent cross-validation resampling technique) for identifying elite futsal players at risk of LE-ST injury. The "model of best fit" of the current study (AUC = 0.767, TP rate = 85% and TN rate = 62%) was comprised by only two hip (flexion with knee extended and abduction) and two ankle (dorsiflexion with knee flexed and extended) ROM measures and 10 different classifiers. Given that these ROM measures require little equipment to be recorded and can be employed quickly (approximately 5 min) and easily by trained staff in a single player, the model developed in this study should be included as an essential component of the injury management strategy in elite futsal.

DATA AVAILABILITY STATEMENT

Data is available online at: https://data.mendeley.com/datasets/s7fs9k3nby/2.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Órgano evaluador de proyectos, Universidad Miguel Hernández de Elche (DPS.FAR.02.14). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.610210/full#supplementary-material

Supplementary File 1 | TRIPOD checklist: prediction model development and validation.

Supplementary File 2 | Description of the personal or individual injury risk factors recorded.

Supplementary File 3 | Description of the psychological risk factors recorded.

Supplementary File 4 | Description of the testing maneuver and measures obtained from the isometric hip abduction and adduction strength test.

Supplementary File 5 | Description of the testing maneuver and measures obtained from the Y-Balance test.

Supplementary File 6 | Description of the testing maneuver and measures obtained from the ROM-Sport battery.

Supplementary File 7 | Descriptions of the resampling, ensemble and cost-sensitive algorithms applied to the base classifiers.

Supplementary File 8 | AUC results (mean and standard deviation) of the personal or individual characteristics data set (DS 1) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 9 | AUC results (mean and standard deviation) of the sleep quality data set (DS 2) for the four base classifiers in isolation and after applying in them the resampling. ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 10 | AUC results (mean and standard deviation) of the Athlete Burnout data set (DS 3) for the four base classifiers in isolation and after applying in them the resampling ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 11 | AUC results (mean and standard deviation) of the psychological characteristics related to sport performance data set (DS 4) for the four base classifiers in isolation and after applying in them the resampling ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 12 | AUC results (mean and standard deviation) of the self-perceived chronic ankle instability data set (DS 5) for the four base classifiers in isolation and after applying in them the resampling. ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 13 | AUC results (mean and standard deviation) of the lower extremity joint ranges of motion data set (DS 6) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 14 | AUC results (mean and standard deviation) of the isometric hip abduction and adduction strength data set (DS 7) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 15 | AUC results (mean and standard deviation) of the dynamic postural control data set (DS 6) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles), and cost-sensitive learning techniques selected.

Supplementary File 16 | AUC results (mean and standard deviation) of the measures obtained through questionnaires data set (DS 6) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles), and cost-sensitive learning techniques selected.

Supplementary File 17 | AUC results (mean and standard deviation) of the field-based tests of neuromuscular performance data set (DS 6) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 18 | AUC results (mean and standard deviation) of the global data set (DS 11) for the five base classifiers in isolation and after applying in them the resampling, ensemble (Classic, Boosting-based, Bagging-based, and Class-balanced ensembles) and cost-sensitive learning techniques selected.

Supplementary File 19 | Schemes of the algorithms selected in data sets (DS) 6, 8, 10, and 11.

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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.

ORIGINAL RESEARCH
published: 05 February 2021
doi: 10.3389/fpsyg.2021.621399

Agreement of Ultra-Short-Term Heart Rate Variability Recordings During Overseas Training Camps in Under-20 National Futsal Players

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Edited by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology,
a section of the journal Frontiers in Psychology

Received: *26 October 2020*
Accepted: *12 January 2021*
Published: *05 February 2021*

Citation:
Chen Y-S, Pagaduan JC, Bezerra P, Crowley-McHattan ZJ, Kuo C-D and Clemente FM (2021) Agreement of Ultra-Short-Term Heart Rate Variability Recordings During Overseas Training Camps in Under-20 National Futsal Players. Front. Psychol. 12:621399. doi: 10.3389/fpsyg.2021.621399

Background: Monitoring the daily change in resting heart rate variability (HRV) can provide information regarding training adaptation and recovery status of the autonomic nervous system (ANS) during training camps. However, it remains unclear whether postural stabilization is essential for valid and reliable ultra-short-term (HRV_{UST}) recordings in short-term overseas training camps.

Design: Observational and longitudinal study.

Purpose: This study aimed to investigate ultra-short-term heart rate variability recordings under stabilization or post-stabilization periods in four overseas training camps.

Participant: Twenty-seven U-20 male national team futsal players voluntarily participated in this study.

Method: Resting HRV was evaluated for 10 min during the early morning of each training camp. The natural logarithm of the root mean square of successive normal-to-normal interval differences (LnRMSSD) was used for comparisons. Time segments of HRV were divided into two periods with three measures within each: (1) the first 30-s (1st_30 s LnRMSSD), the first 60-s (1st_60 s LnRMSSD), and the 5-min standard (1st_5 min LnRMSSD) during stabilization; (2) the first 30-s (2nd_30 s LnRMSSD), the first 60-s (2nd_60 s LnRMSSD), and the 5-min standard (2nd_5 min LnRMSSD) after stabilization.

Result: The results demonstrated trivial to small ES (−0.03; 0.46), very large to nearly perfect ICC (0.76; 0.98), and narrow range of SEM (0.06; 0.31) when all time segments of HRV_{UST} were compared to the 1st_5 min and 2nd_5 min HRV. Furthermore, the magnitude of the correlation coefficients ranged from very high to nearly perfect for all the time segments ($r = 0.83$; 0.97). The HRV_{UST} posted excellent agreement in all time segments (bias = −0.05; 0.12) with/without postural stabilization. Trivial to small levels of effect size in all time segments of $LnRMSSD_{mean}$ (0.02; 0.41 ES) and $LnRMSSD_{CV}$ (−0.49; −0.02 ES) across overseas training camps was identified.

Conclusion: The first 30 or 60-s LnRMSSD recordings can be used to evaluate daily cardiac-autonomic function during overseas training camps in futsal players. The process for stabilization seems to be unnecessary for measuring the morning resting LnRMSSD in overseas training camps among young adult futsal players.

Keywords: heart rate variability, autonomic nervous system, overseas training camps, futsal training, ultra-short-term recording

INTRODUCTION

Heart rate (HR) variability (HRV) is a neurophysiological marker that reflects the cardiac-related activation regulated by the autonomic nervous system (ANS) (Buchheit, 2014). Assessment of HRV requires recording a time series of HR beat-to-beat intervals (R wave-to-R wave interval, RRI) via a non-invasive electrocardiographic device (ECG) or a HR monitor sensor. The measurement of HRV can help sports practitioners and coaches interpret autonomic function in terms of training adaptations (i.e. increase in RRI is associated with improvement of aerobic capacity) (Sandercock et al., 2005; Plews et al., 2013a), recovery status (Buchheit et al., 2007; Nakamura et al., 2009; Chen et al., 2019), and autonomic health during international competitions (Flatt and Howells, 2019; Flatt et al., 2019; Muñoz-López et al., in press).

The standard process to collect HRV data requires a 5-min short-term recording period preceded by a 5-min stabilization period (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology., 1996). However, this assessment method is limited to specific circumstances, i.e., during traditional training schedules, due to the time-consuming nature of this type of assessment. Yet, with recent methodological developments, the assessment of ultra-short-term HRV (HRV_{UST}), HRV recording of <60 s, have been established to improve the usability of this technique in field-based settings (Castaldo et al., 2019).

In a practical sense, HRV_{UST} assessment during sports training can be used to understand cardiac modulation during exercise or physiological adaption after an acute and chronic training regime. Nakamura et al. (2015) reported excellent limits of agreement and acceptance in 1-min HRV_{UST}(natural logarithm of the root mean square of successive normal-to-normal interval differences, $LnRMSSD_{UST}$), compared to a criterion of 5-min LnRMSSD (a 5-min HRV record after 5-min stabilization). The correlation between changes in $LnRMSSD_{UST}$ (i.e., 0–1; 1–2; 2–3; 3–4; 4–5 min) and LnRMSSD criterion was between 0.45 and 0.75, with the highest value ($r = 0.75$; 90% CI: 0.55–0.85) found between $LnRMSSD_{UST}$ at 1–2 min and LnRMSSD criterion, indicating measurement validity and agreement of HRV_{UST} assessment after 1-min of stabilization. In addition, Krejčí et al. (2018) compared $LnRMSSD_{UST}$ every 30 s in 5-min stabilization records to a 5-min criterion (6–10 min) in 30 endurance athletes at the national level (10 ski runners, 8 road cyclists, and 12 cross-country skiers) and 30 university students. When $LnRMSSD_{UST}$ and HR were measured in the supine position, the minimal stabilization period to stabilize both indices was 60-s for endurance athletes and 90-s for university students for valid and reliable estimations. Interestingly, Pereira et al. (2016) demonstrated excellent reliability and limits of agreement of 1-min HRV_{UST} during 5-min stabilization in 35 elite futsal players. An additional observation in an athletic population reported by Flatt and Esco (2016) also supports this notion. However, interpretation of these findings may be limited due to the heterogeneity of the sample pools from mixed genders and training regimens. Despite the time efficiency of data collection using HRV_{UST}, there are no standard recommendations for using HRV_{UST} with or without stabilization.

Monitoring the daily change in resting HRV can provide information regarding training adaptation and recovery status of ANS health during national team training camps (Flatt and Howells, 2019; Flatt et al., 2019). During a national team training camp, soccer players who played more than 60 min of match play experienced augmented ANS modulation (by measuring daily morning LnRMSSD) after a friendly match. This profound effect lasting for 72 h after (Muñoz-López et al., in press). Thus, it is important to monitor the HRV parameters for assessing recovery status during training camps. It was recently observed that 30-s mean value of LnRMSSD ($LnRMSSD_{mean}$) measure was accurate and valid compared to the standard 5-min LnRMSSD measure during both training camps (domestic and overseas) and international competition in a male U-20 national futsal team. In contrast, coefficient of variation of LnRMSSD ($LnRMSSD_{cv}$) measure required at least 2 min recordings to provide valid and reliable HRV measures during training camps (Chen et al., 2020; Clemente F. M et al., 2020). However, the interpretation of these findings were highlighted as being after 5-min postural stabilization period.

Monitoring $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ can help us to understand the vagal-related adaptation and psychophysiological status associated with physical fitness during training period (i.e., increase in $LnRMSSD_{mean}$, decrease in $LnRMSSD_{cv}$, and improvement of aerobic capacity) (Nakamura et al., 2020). Most of previous studies reported agreement of HRV_{UST} based on crossectional designs, in this study, weekly HRV_{UST} of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ was investigated during four overseas training camp in a male U-20 national futsal team. In light of the abovementioned studies, the purpose of this study was twofold. Firstly, to compare HRV_{UST} recordings within stabilization and after stabilization periods during short-term overseas training camps in U-20 national futsal players as a surrogate to the traditional 5-min standard measures. Secondly, to compare the variation of HRV_{UST} measures among short-term overseas training camps. It was hypothesized that HRV_{UST}

recordings during stabilization and after stabilization would show similar degrees of agreement and reproducibility to 5-min HRV records. The secondary hypothesis was that HRV_{UST} would show similar characteristics among overseas training camps.

MATERIALS AND METHODS

Experimental Approach to the Problem

This study was a cross-sectional and observational study. Morning resting HRV was measured in four overseas training camps prior to the Asian U-20 Futsal Championship final. The HRV_{UST} assessment during the first 5-min (stabilization) and second 5-min (after stabilization) was compared. The time segments of HRV records were divided into the first 30-s (1st_30 s LnRMSSD), the first 60-s (1st_60 s LnRMSSD), and the 5-min recording (1st_5 min LnRMSSD) during stabilization, and the first 30-s (2nd_30 s LnRMSSD), the first 60-s (2nd_60 s LnRMSSD), and the 5-min recording (2nd_5 min LnRMSSD) after stabilization.

The number of participating players varied from camp to camp due to budgeting and logistical issues (1st training camp: 6 days, 15 players; 2nd training camp: 5 days, 20 players; 3rd training camp: 6 days, 17 players; 4th training camp: 10 days, 14 players). The players involved in the fourth oversea training camp were the final registered players for the continental tournament. All assessments were conducted during the overseas training camps prior to the 2019 Asian Football Confederation U-20 Futsal Championship Final (Tabriz, Iran). **Table 1** shows detailed information regarding the schedule of four overseas training camps.

Experimental Procedure

During each oversea training camp, the players were lodged in a domestic hotel one night before international travel. All players undertook daily resting HRV measures before breakfast in the early morning during the training camps. The players were instructed to maintain a comfortable sitting position for resting HRV assessment. The players were informed to control their breathing with their preferred patterns while their eyes were closed. The morning resting HRV was recorded via an individual portable Polar HR monitor (Polar team Pro, Polar Electro, Kemple, Finland). All sensors were synced to a Polar team pro dock. All data were uploaded to a secure cloud server and then subsequently exported to a laptop for data analysis. The duration of the resting HRV assessment was 10-min. All measures were performed in a quiet and spacious meeting room between 7 a.m. and 8 a.m. in local time.

Participants

Twenty-four outfield players and three goalkeepers, male futsal players were recruited and voluntarily participated this study from Chinese Taipei U-20 national futsal team (mean ± standard deviation: age = 17.93 ± 0.87 yrs; height = 1.71 ± 0.07 m; body weight = 65.39 ± 9.39 kg; body fat = 12.54 ± 2.76 %; maximal aerobic capacity = 51.98 ± 3.07 $ml \cdot kg^{-1} \cdot min^{-1}$). The players signed informed consent forms and were all familiarized with experimental procedures prior to participation. The study was approved by the Human Ethics Committee of the University of Taipei (UT-IRB-2018-068) and undertaken in accordance with the Declaration of Helsinki and its later amendments in 2013.

Heart Rate Variability

A portable telemetric HR monitor system was used to record the resting HRV (Polar team Pro, Polar Electro, Kemple, Finland). Each player was issued an HR sensor and HR strap for the entire duration of the training camp. Kubios HRV analysis software (Premium version 3.2.0., Kubios, Kuopio, Finland) was used to calculate LnRMSSD. Artifact correction was set at a medium threshold level, and the window width was set at 300 s with a window overlap of 50%. Smoothing priors set at 500 Lambda were used for detrending methods (Tarvainen et al., 2014). If the percentage of ectopic beats in daily measure were >5%, then the data was excluded from the analysis.

Statistical Analyses

Descriptive data of the measured variables are presented as $LnRMSSD_{mean}$ or $LnRMSSD_{cv}$ and standard deviation (SD). Inter-differences of HRV_{UST} to standard values was analyzed by using Cohen's d effect size (ES). The level of ES was interpreted as trivial (0.0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), very large (>2.0) (Hopkins et al., 2009). For reliability analysis, interclass correlation coefficients (ICC) with a two-way random model and a single measure were used to determine relative reliability. The level of ICC values were assessed as nearly perfect (0.9–1), very large (0.70–89), large (0.50–69), moderate (0.31–49), and small (0–0.3) (Hopkins et al., 2009). Moreover, the standard error of measurement (SEM) was used to analyzed the absolute values of reliability. The SEM was calculated as $SD \cdot \sqrt{1 - ICC}$ (Weir, 2005). For validity analysis, the relationship of HRV recordings between each time segment were assessed via Pearson product-moment correlation coefficient (r). The magnitude of the correlation coefficients was determined as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), high ($0.5 < r < 0.7$), very high ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$), and perfect ($r = 1$) (Hopkins et al., 2009). In addition, Bland–Altman plots were used to evaluate the upper and lower limits of agreements among all time segments of LnRMSSD (Bland and Altman, 1986). Statistical analyses were conducted using by SPSS® Statistics version 25.0 (IBM, Armonk, NY, USA) and Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

RESULT

Agreement and Reliability of Ultra-Short-Term Heart Rate Variability

The daily HRV recordings from all players were compliance with full attendance during the training camps. For $LnRMSSD_{mean}$, small ES and very large ICC values were found between the 1st_30 s and 1st_5 min, or 1st_30 s, and 2nd_5 min in the 2nd training camp. A similar finding was reported in the 3rd training camp, except for the ICC comparison of the 1st_30 s and 1st_5 min. Moderate ES and very large ICC values

TABLE 1 | The schedule of overseas training camps prior to the continental tournament final.

Location	Date	Duration (days)	Players (numbers)	Training sessions (sessions)	Friendly matches (games)
1st TC Shenzhen, China	July 28th–August 2nd 2018	6	15	1 session (115-min)	4 games (89, 100, 101, 91-min)
2nd TC Nagoya, Japan	November 19th−23th 2018	5	20	3 sessions (109, 128, 126, 76-min,)	3 games (97, 75, 77-min)
3rd TC Osaka, Japan	April 7th−12th 2019	6	17	4 sessions (91, 108, 95, 117-min)	4 games (107, 101, 102, 90-min)
4th TC Luso, Portugal	June 1st−10th 2019	10	14	3 sessions (83, 73, 90-min)	5 games (87, 82, 78, 83, 67-min)

TC, training camp.

TABLE 2 | Mean of natural logarithm of root mean square differences between adjacent normal R–R intervals (LnRMSSD) during 0–30 s, 0–60 s, and 0–5 min criterion in stabilization (1st_5 min) and after stabilization (2nd_5 min) assessments.

Training camp	Parameters	ES (90% CI)		ICC (90% CI)		SEM		Bias (± 1.96*SD)	
		1st_5 min	2nd_5 min	1st_5 min	2nd_5 min	1st_5 min	2nd_5 min	1st_5 min	2nd_5 min
1st training camp (*n* = 15)	1st_30 s	−0.13 (−0.73; 0.47)*	−0.08 (−0.69; 0.52)*	0.87 (0.93; 0.99)‡	0.82 (0.61; 0.92)‡	0.14	0.17	−0.06 (−0.52; 0.40)	−0.05 (−0.61; 0.52)
	1st_60 s	−0.14 (−0.74; 0.46)*	−0.10 (−0.70; 0.50)*	0.95 (0.88; 0.98)§	0.91 (0.79; 0.96)§	0.10	0.14	−0.06 (−0.35; 0.23)	−0.05 (−0.47; 0.37)
	2nd_30 s	0.07 (−0.53; 0.67)*	0.10 (−0.50; 0.70)*	0.95 (0.89; 0.98)§	0.97 (0.92; 0.99)§	0.14	0.11	0.05 (−0.31; 0.40)	0.06 (−0.22; 0.34)
	2nd_60 s	0.12 (−0.48; 0.72)*	0.15 (−0.45; 0.75)*	0.95 (0.87; 0.98)§	0.95 (0.87; 0.99)§	0.14	0.14	0.08 (−0.30; 0.45)	0.09 (−0.25; 0.43)
2nd training camp (*n* = 20)	1st_30 s	0.24 (−0.28; 0.77)#	0.22 (−0.39; 0.84)#	0.86 (0.69; 0.94)‡	0.76 (0.52; 0.89)‡	0.24	0.31	0.16 (−0.42; 0.73)	0.20 (−0.56; 0.96)
	1st_60 s	0.16 (−0.36; 0.68)*	0.11 (−0.50; 0.73)*	0.91 (0.80; 0.96)§	0.82 (0.64; 0.91)‡	0.20	0.28	0.11 (−0.39; 0.61)	0.15 (−0.54; 0.85)
	2nd_30 s	0.06 (−0.46; 0.59)*	−0.07 (−0.68; 0.54)*	0.90 (0.79; 0.95)§	0.88 (0.76; 0.94)‡	0.20	0.22	0.04 (−0.51; 0.59)	0.09 (−0.49; 0.67)
	2nd_60 s	−0.03 (−0.49; 0.55)*	0.11 (−0.41; 0.63)*	0.92 (0.83; 0.96)§	0.91 (0.81; 0.96)§	0.18	0.19	0.02 (−0.47; 0.51)	0.07 (−0.44; 0.58)
3rd training camp (*n* = 17)	1st_30 s	0.22 (−0.34; 0.79)#	0.46 (−0.11; 1.04)#	0.93 (0.76; 0.97)§	0.84 (0.19; 0.95)‡	0.12	0.18	0.11 (−0.19; 0.41)	0.22 (−0.09; 0.52)
	1st_60 s	0.12 (−0.45; 0.68)*	0.33 (−0.24; 0.90)#	0.98 (0.94; 0.99)§	0.90 (0.52; 0.97)§	0.07	0.16	0.05 (−0.13; 0.24)	0.16 (−0.13; 0.45)
	2nd_30 s	−0.07 (−0.64; 0.49)*	0.11 (−0.45; 0.68)*	0.96 (0.92; 0.98)§	0.93 (0.84; 0.97)§	0.12	0.16	−0.04 (−0.34; 0.25)	0.06 (−0.33; 0.45)
	2nd_60 s	−0.07 (0.64; 0.49)*	0.11 (−0.45; 0.68)*	0.98 (0.94; 0.99)§	0.95 (0.88; 0.98)§	0.08	0.13	−0.04 (−0.27; 0.18)	0.06 (−0.25; 0.37)
4th training camp (*n* = 14)	1st_30 s	0.15 (−0.47; 0.77)*	0.17 (−0.45; 0.80)*	0.96 (0.87; 0.99)§	0.90 (0.77; 0.96)§	0.08	0.13	0.06 (−0.13; 0.26)	0.07 (−0.25; 0.40)
	1st_60 s	0.12 (−0.50; 0.74)*	0.14 (−0.48; 0.77)*	0.98 (0.93; 0.99) §	0.94 (0.85; 0.98)§	0.06	0.10	0.05 (−0.08; 0.18)	0.06 (−0.20; 0.32)
	2nd_30 s	0.24 (−0.38; 0.87)#	0.27 (−0.35; 0.90)#	0.85 (0.64; 0.94)‡	0.90 (0.68; 0.96)§	0.16	0.13	0.10 (−0.31; 0.51)	0.11 (−0.18; 0.40)
	2nd_60 s	0.10 (−0.52; 0.72)*	0.12 (−0.50; 0.75)*	0.94 (0.86; 0.98) §	0.97 (0.90; 0.97)§	0.10	0.07	0.04 (−0.22; 0.31)	0.05 (−0.10; 0.21)

*The level of effect size was symbolled as trivial (0.0–0.2) as * and small (0.2–0.6) as #. The level of interclass correlation coefficients was denoted small (0–0.3) as *, moderate (0.31–49) as #, very large (0.70–89) as ‡, and nearly perfect (0.9–1) as §. ES, effect size; ICC, interclass correlation coefficients; CI, confident interval; SEM, standard error of measurement; SD, standard deviation; n, numbers.*

were also found between the 2nd_30 s and 1st_5 min, or the 1st_30 s and 2nd_5 min. The other comparisons showed trivial ES and nearly perfect ICC values (**Table 2**). For $LnRMSSD_{cv}$, a wide range of ES (−0.91; −0.02) and ICC (0.23; 0.88) values were found among the overseas training camps (**Table 3**). In **Figure 1**, the results of $LnRMSSD_{mean}$ exhibited nearly perfect

TABLE 3 | Coefficient of variation of natural logarithm of root mean square differences between adjacent normal R–R intervals (LnRMSSD) during 0–30 s, 0–60 s, and 0–5 min criterion in stabilization (1st_5min) and after stabilization (2nd_5min) assessments.

Training camp	Parameters	ES (90% CI)		ICC (90% CI)		SEM		Bias (± 1.96*SD)	
		1st_5 min	2nd_5 min	1st_5 min	2nd_5 min	1st_5 min	2nd_5 min	1st_5 min	2nd_5 min
1st training camp (*n* = 15)	1st_30 s	−0.55 (−1.17; 0.05)#	−0.56 (−1.18; 0.05)#	0.38 (0.01; 0.68)#	0.23 (−0.16; 0.58)*	3.04	3.39	−2.14 (−10.07; 5.78)	−2.23 (−11.56; 7.10)
	1st_60 s	−0.34 (−0.95; 0.26)#	−0.35 (−0.97; 0.25)#	0.59 (0.23; 0.81)†	0.44 (0.37; 0.72)#	2.32	2.72	−1.28 (−7.67; 5.12)	−1.36 (−9.15; 6.42)
	2nd_30 s	−0.66 (−1.29; 0.05)†	−0.66 (−1.29; 0.06)†	0.40 (0.02; 0.69)#	0.44 (0.05; 0.72)#	4.80	4.63	−3.44 (−13.70; 6.83)	−3.52 (−13.38; 6.33)
	2nd_60 s	−0.56 (−1.18; 0.05)#	−0.57 (−1.19; 0.04)#	0.49 (0.10; 0.75) #	0.53 (0.14; 0.78)†	3.98	3.82	−2.72 (−11.49; 6.05)	−2.81 (−11.16; 5.54)
2nd training camp (*n* = 20)	1st_30 s	−0.45 (−0.98; 0.08)#	−0.38 (0.90; 0.15)#	0.52 (0.20; 0.74)†	0.64 (0.35; 0.81)†	4.57	3.95	−2.85 (−14.35; 8.66)	−2.16 (−11.09; 6.78)
	1st_60 s	−0.13 (−0.65; 0.39)*	−0.02 (−0.54; 0.50)*	0.88 (0.76; 0.94)‡	0.81 (0.63; 0.91)‡	2.06	2.59	−0.80 (−6.44; 4.85)	−0.11 (−6.61; 6.40)
	2nd_30 s	−0.31 (−0.84; 0.21)#	−0.23 (−0.76; 0.29)#	0.76 (0.53; 0.88)‡	0.51 (0.18; 0.74)†	3.99	3.99	−2.24 (−11.30; 6.82)	−1.55 (−14.35; 11.25)
	2nd_60 s	−0.23 (−0.76; 0.29)#	−0.17 (−0.67; 0.38)*	0.82 (0.64; 0.91)‡	0.65 (0.37; 0.82)†	3.32	3.32	−1.63 (−9.43; 6.18)	−0.94 (−11.48; 9.60)
3rd training camp (*n* = 17)	1st_30 s	−0.65 (−1.24; 0.08)†	−0.87 (−1.48; 0.29)†	0.58 (0.13; 0.81)†	0.39 (−0.01; 0.68)#	3.32	4.01	−3.21 (−10.58; 4.16)	−4.06 (−12.71; 4.58)
	1st_60 s	−0.32 (−0.89; 0.25)#	−0.54 (−1.12; 0.03)#	0.81 (0.57; 0.92)‡	0.61 (0.23; 0.82)†	1.96	2.81	−1.45 (−6.28; 3.38)	−2.30 (−8.75; 4.15)
	2nd_30 s	−0.34 (−0.91; 0.23)#	−0.55 (−1.13; 0.02)#	0.69 (0.40; 0.85)†	0.63 (0.23; 0.83)†	2.68	2.93	−1.59 (−8.48; 5.31)	−2.44 (−8.86; 3.98)
	2nd_60 s	−0.11 (−0.68; 0.45)*	−0.31 (−0.88; 0.25)#	0.80 (0.59; 0.91)‡	0.83 (0.59; 0.93)‡	2.13	1.96	−0.53 (−6.34; 5.28)	−1.38 (−5.84; 3.07)
4th training camp (*n* = 14)	1st_30 s	−0.91 (−1.58; 0.27)†	−0.66 (−1.31; 0.03)†	0.51 (−0.03; 0.79)†	0.57 (0.11; 0.82)†	2.86	2.68	−3.33 (−8.59; 1.93)	−2.50 (−8.23; 3.22)
	1st_60 s	−0.54 (−1.18; 0.09)#	−0.31 (−0.94; 0.31)#	0.71 (0.23; 0.89)‡	0.77 (0.49; 0.90)‡	2.33	2.07	−2.05 (−6.51; 2.41)	−1.23 (−6.00; 3.55)
	2nd_30 s	−0.67 (−1.32; 0.04)†	−0.51 (−1.16; 0.11)#	0.23 (−0.14; 0.58)*	0.45 (0.06; 0.74)†	6.33	5.35	−3.79 (−16.82; 9.24)	−2.96 (−13.98; 8.06)
	2nd_60 s	−0.47 (−1.12; 0.15)#	−0.27 (−0.90; 0.35)#	0.51 (0.12; 0.77)†	0.76 (0.49; 0.90)‡	3.33	2.33	−1.95 (−9.31; 5.42)	−1.12 (−6.46; 4.22)

*The level of effect size was symbolled as trivial (0.0–0.2) as *, small (0.2–0.6) as # and moderate (0.6–1.2) as †. The level of interclass correlation coefficients was denoted small (0–0.3) as *, moderate (0.31–49) as #, large (0.50–69) as † and very large (0.70–89) as ‡. ES, effect size; ICC, interclass correlation coefficients; CI, confident interval; SEM, standard error of measurement; SD, standard deviation; n, numbers.*

correlations in all correlations analyses except for a very high correlation between the 2nd_5 min and 1st_30 s (0.83, $p < 0.001$), and 2nd_5 min and 1st_60 s (0.88, $p < 0.001$). In **Figure 2**, the results of LnRMSSD_{cv} demonstrate high (0.59–0.77, $p < 0.001$) to very high (0.72–0.83, $p < 0.001$) correlations in all comparisons.

In **Figure 3**, the results of LnRMSSD_{mean} show excellent limits of agreement in all time segment comparisons. The

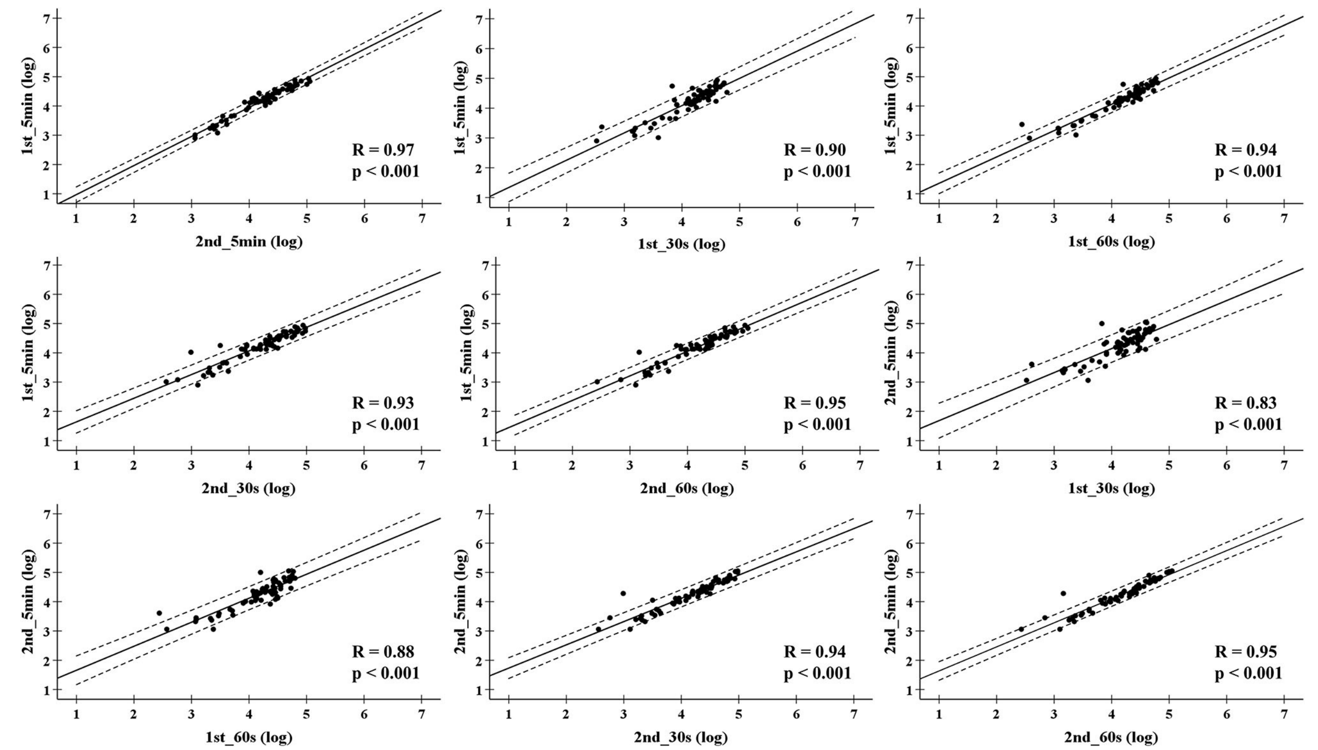

FIGURE 1 | Pearson correlation coefficient for the mean of natural logarithm of the root mean square differences between adjacent normal R-R intervals in all time segments during four overseas training camps. 1st_5 min = The first 5-min LnRMSSD; 1st_30 s = The first 30 s LnRMSSD; 1st_60 s = The first 60 s LnRMSSD; 2nd_5 min = The 6-10 min LnRMSSD; 2nd_30 s = The secondary 30 s LnRMSSD; 2nd_60 s = The secondary 60 s LnRMSSD.

smallest mean difference and the upper and lower limits of agreements was found in the 1st_5 min and 2nd_5 min comparison (difference = −0.05, +1.96 s = −0.29, −1.96 s = 0.19). In **Figure 4**, the results of $LnRMSSD_{cv}$ demonstrate a wide range of limits of agreement in all time segment comparisons.

Comparison of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ Among Overseas Training Camps

The descriptive results of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ for all time segments during four different overseas training camps are presented in **Table 4**. Collectively, pairwise comparisons showed trivial to small ES in $LnRMSSD_{mean}$ (0.02; 0.41 ES) and $LnRMSSD_{cv}$ (−0.02; −0.49 ES) across overseas training camps.

DISCUSSION

This study is the first to report the reliability and validity of HRV_{UST} during a series of overseas training camps in male U-20 national team futsal players. The primary findings of the present study revealed that the 30 and 60 s HRV_{UST} measure during stabilization and post-stabilization periods were valid and acceptable measures for LnRMSSD assessment and can be used as a surrogate for the standard 5-min recording. In addition, the secondary finding in the present study showed trivial to small levels of effect size in all time segments of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ across overseas training camps.

Agreement and Reliability of Ultra-Short-Term Heart Rate Variability

The present study attempted to investigate the agreement of HRV_{UST} assessment for cardiac-autonomic adaptation during and after the stabilization process. The results of $LnRMSSD_{mean}$ demonstrated trivial to small ES, very large to nearly perfect ICC, and narrow range of SEM (0.06–0.31) when all time segments of HRV_{UST} were compared to the 1st_5 min and 2nd_5 min HRV. Furthermore, the magnitude of the correlation coefficients was nearly perfect when the 1st_5 min was compared to all the time segments (r = 0.90–0.97). In terms of agreement of HRV_{UST}, we found that there was excellent acceptance in all time segments. Indeed, perfect agreement was found between the 1st_5 min and 2nd_5 min HRV comparison (narrow risk of bias and limits of agreement). These findings indicate an absence of stabilization prior to HRV_{UST} measurement is acceptable for the accuracy of HRV measurement during overseas training camps. Our laboratory recently reported acceptance of 30-s HRV_{UST} of $LnRMSSD_{mean}$ measure during short-term training camps in young adult futsal players (Chen et al., 2020). Nakamura et al. (2020) compared the limits of agreement between a standard 10 min LnRMSSD (5-min stabilization and 5-min HRV record) and

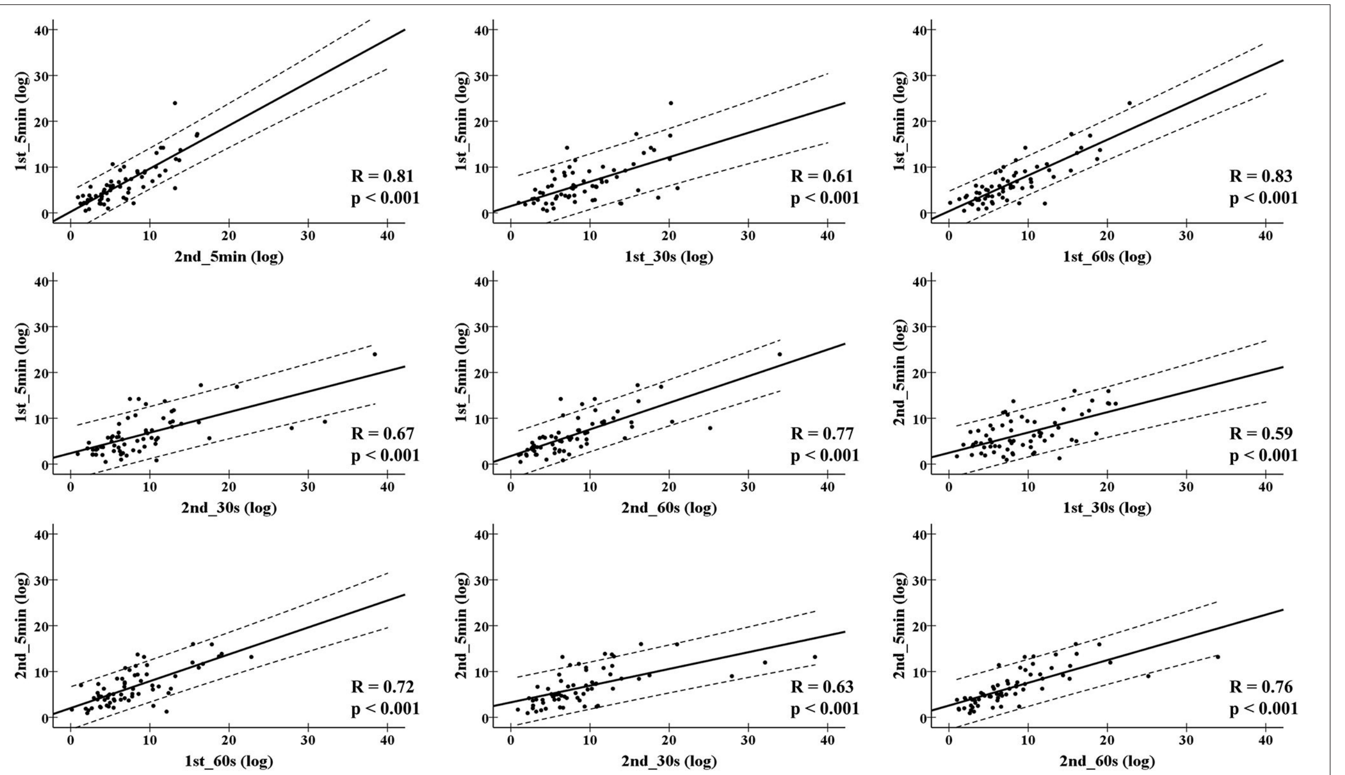

FIGURE 2 | Pearson correlation coefficient for the coefficient of variation of natural logarithm of the root mean square differences between adjacent normal R-R intervals in all time segments during four overseas training camps. 1st_5 min = The first 5-min LnRMSSD; 1st_30 s = The first 30 s LnRMSSD; 1st_60 s = The first 60 s LnRMSSD; 2nd_5 min = The 6-10 min LnRMSSD; 2nd_30 s = The secondary 30 s LnRMSSD; 2nd_60 s = The secondary 60 s LnRMSSD.

$LnRMSSD_{UST}$ (1–2 min record followed by 1-min stabilization) in 11 male futsal players before and after 4-weeks of pre-season training. Nakamura's et al. study showed meaningful changes in HRV_{UST} measures in response to a futsal pre-season (these results indicate a progressive increase in the vagal activity and reduction of training-induced perturbation of cardiac autonomic homeostasis over the futsal pre-season). Excellent agreement and reliability of HRV_{UST} after 1 min stabilization has also been reported in athletic populations (Esco and Flatt, 2014; Nakamura et al., 2015; Flatt and Esco, 2016; Pereira et al., 2016). Our observation further supports the notion of implementing HRV_{UST} recording by measuring weekly $LnRMSSD_{mean}$ during overseas training camps due to the very high and nearly perfect correlation coefficient and a narrow range of limits of agreement during all time segments. Indeed, all players in our study were familiarized with the procedure of HRV measurement in order to increase the accuracy of recording. Collectively, our findings demonstrate consistent excellent agreement of HRV_{UST} of weekly $LnRMSSD_{mean}$ during overseas training camps without the conventional 5-min postural stabilization period recommended when LnRMSSD is used for HRV recording.

The results of $LnRMSSD_{cv}$ demonstrated trivial to large ES, small to very large ICC when HRV_{UST} parameters were used to compare the 1st_5 min and 2nd_5 min HRV. In addition, high to very high correlations and a wide range of limits of agreement in all time segments of $LnRMSSD_{cv}$ comparisons were identified (**Figures 2**, **4**). It seems that the shortened $LnRMSSD_{cv}$ recording less than 1 min may increase the bias of measurement. Our laboratory recently reported that HRV_{UST} of $LnRMSSD_{cv}$ could not be used as a surrogate of 5 min standard HRV records during short-term training camps due to inaccuracy of measures (Chen et al., 2020). It is important to note that $LnRMSSD_{cv}$ increases in association with perception of fatigue and reduce of physical performance (Flatt et al., 2017a). Previous studies have demonstrated that 1-min $LnRMSSD_{cv}$ measure after 1-min postural stabilization is sensitive to physical adaptation in response to periodization of training loads in women soccer players (Flatt and Esco, 2015), rugby seven players (Flatt and Howells, 2019), sprint swimmers (Flatt et al., 2017b), and futsal players (Nakamura et al., 2020). Interestingly, in our study, 60 s HRV_{UST} of $LnRMSSD_{cv}$ demonstrated better ICC values, magnitude of correlation coefficient, and agreement of measures than 30 s HRV_{UST} of $LnRMSSD_{cv}$ despite stabilization or after stabilization period. Nevertheless, cautions should be taken when $LnRMSSD_{cv}$ are used to evaluate ANS adaptation during training camps.

Comparisons of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ Among Oversea Training Camps

As demonstrated in **Table 4**, in comparison with $LnRMSSD_{mean}$ among overseas training camps, trivial ES was observed in 1st_5 min, 2nd_30 s, 2nd_60 s, and 2nd_5in time segments. In contrast, trivial to small ES in 1st_30 s and 1st_60 s time

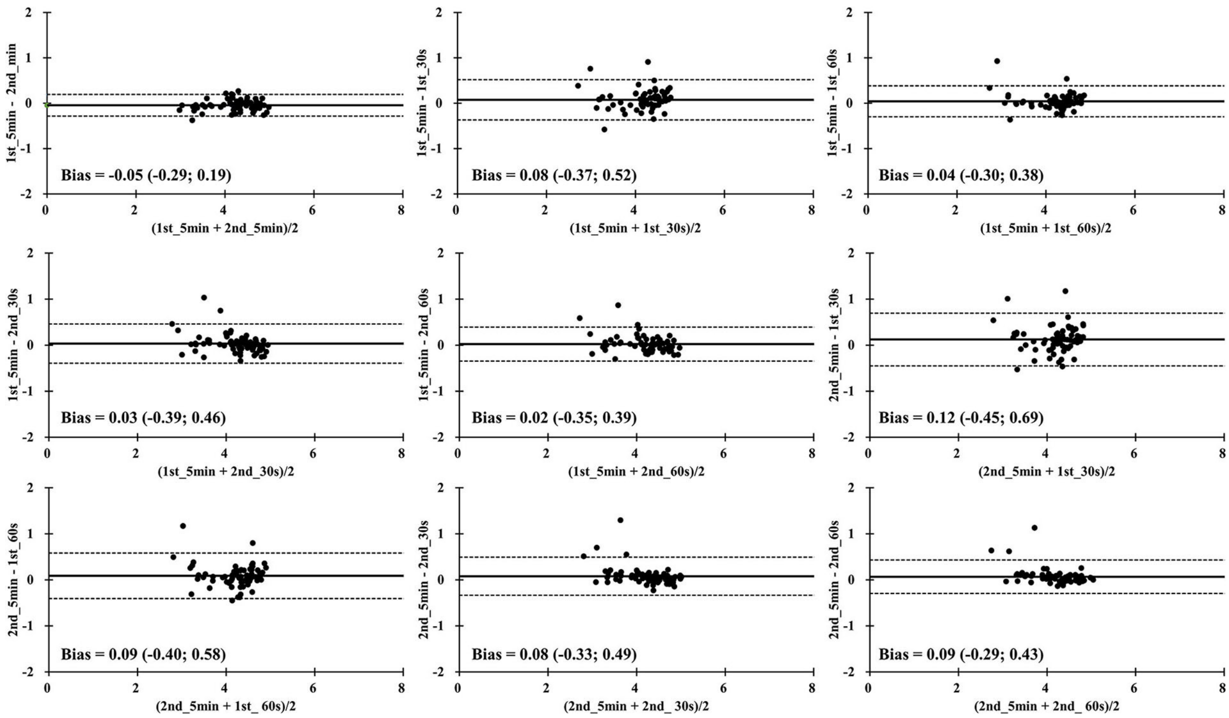

FIGURE 3 | Bland-Altman plots for the mean of natural logarithm of the root mean square differences between adjacent normal R-R intervals in all time segments during four overseas training camps. 1st_5min = The first 5-min LnRMSSD; 1st_30 s = The first 30 s LnRMSSD; 1st_60 s = The first 60 s LnRMSSD; 2nd_5 min = The 6-10 min LnRMSSD; 2nd_30 s = The secondary 30 s LnRMSSD; 2nd_60 s = The secondary 60 s LnRMSSD.

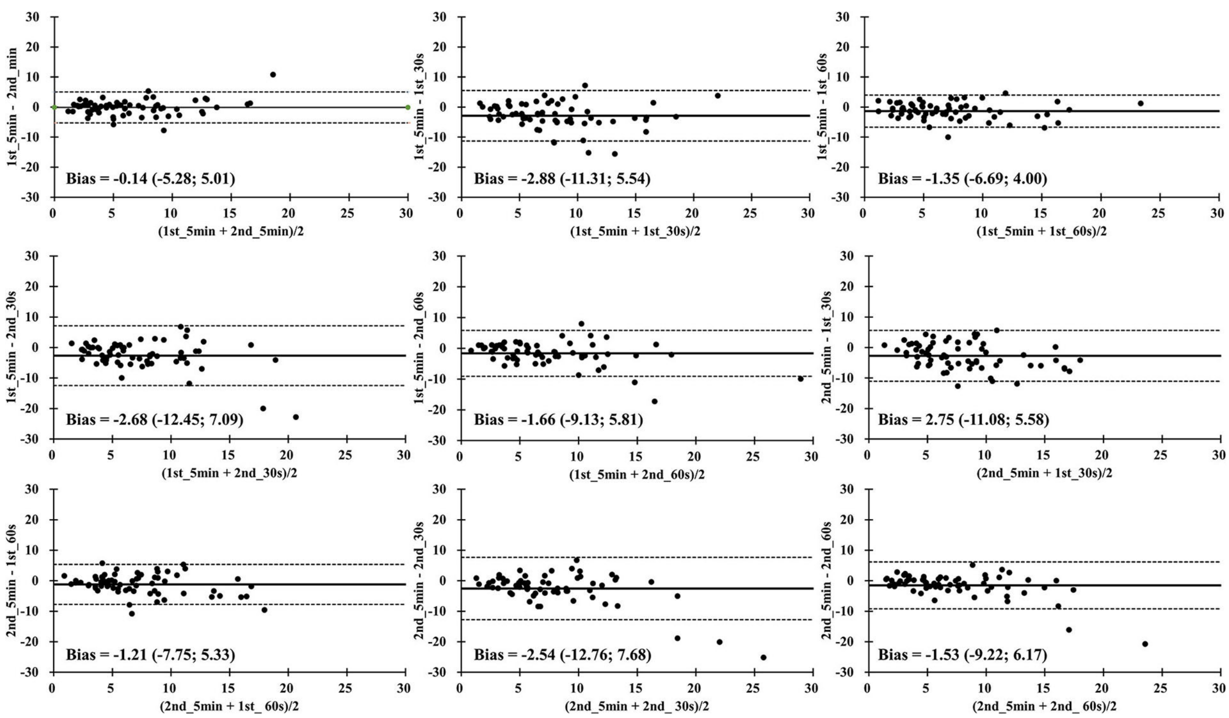

FIGURE 4 | Bland-Altman plots for the coefficient of variation of natural logarithm of the root mean square differences between adjacent normal R-R intervals in all time segments during four overseas training camps. 1st_5 min = The first 5-min LnRMSSD; 1st_30 s = The first 30 s LnRMSSD; 1st_60 s = The first 60 s LnRMSSD; 2nd_5 min = The 6-10 min LnRMSSD; 2nd_30 s = The secondary 30 s LnRMSSD; 2nd_60 s = The secondary 60 s LnRMSSD.

TABLE 4 | Natural logarithm of the root mean square differences between adjacent normal R–R intervals (mean and coefficient of variation values) in first 30 s, first 60 s, and 5 min time segments during stabilization vs after stabilization in four overseas training camps.

	1st TC	2nd TC	3rd TC	4th TC	1 vs. 2 ES	1 vs. 3 ES	1 vs. 4 ES	2 vs. 3 ES	2 vs. 4 ES	3 vs. 4 ES
LnRMSSDmean										
1st_5 min	4.21 ± 0.53	4.19 ± 0.57	4.22 ± 0.52	4.20 ± 0.40	0.04 (−0.53; 0.60)	−0.02 (−0.60; 0.56)	0.02 (−0.59; 0.63)	−0.05 (−0.60; 0.49)	−0.02 (−0.59; 0.55)	0.04 (−0.55; 0.64)
1st_30 s	4.27 ± 0.39	4.04 ± 0.64	4.11 ± 0.45	4.14 ± 0.40	0.41 (−0.15; 0.99)	0.37 (−0.21; 0.96)	0.32 (−0.29; 0.94)	−0.12 (−0.67; 0.42)	−0.18 (−0.75; 0.40)	−0.07 (−0.66; 0.52)
1st_60 s	4.28 ± 0.46	4.09 ± 0.67	4.16 ± 0.50	4.15 ± 0.42	0.32 (−0.25; 0.89)	−0.12 (−0.70; 0.47)	0.29 (−0.32; 0.91)	−0.11 (−0.66; 0.43)	−0.10 (−0.68; 0.47)	0.02 (−0.57; 0.62)
2nd_5 min	4.23 ± 0.54	4.24 ± 0.57	4.32 ± 0.45	4.21 ± 0.39	−0.02 (−0.58; 0.54)	−0.15 (−0.74; 0.43)	0.04 (−0.57; 0.65)	−0.15 (−0.70; 0.39)	0.06 (−0.51; 0.63)	0.25 (−0.34; 0.85)
2nd_30 s	4.17 ± 0.63	4.15 ± 0.65	4.26 ± 0.60	4.10 ± 0.41	0.03 (−0.53; 0.59)	−0.19 (−0.78; 0.39)	0.13 (−0.48; 0.74)	−0.17 (−0.72; 0.37)	0.09 (−0.49; 0.66)	0.30 (−0.29; 0.90)
2nd_60 s	4.14 ± 0.65	4.17 ± 0.63	4.26 ± 0.57	4.16 ± 0.40	−0.05 (−0.61; 0.52)	−0.19 (−0.78; 0.39)	−0.04 (−0.65; 0.58)	−0.15 (−0.69; 0.40)	0.02 (−0.56; 0.59)	0.19 (−0.40; 0.79)
LnRMSSDcv										
1st_5 min	7.01 ± 3.71	5.39 ± 5.91	7.35 ± 4.47	6.33 ± 2.96	0.31 (−0.25; 0.88)	−0.08 (−0.65; 0.50)	0.20 (−0.40; 0.80)	−0.36 (−0.92; 0.18)	−0.19 (−0.76; 0.39)	0.26 (−0.34; 0.86)
1st_30 s	9.15 ± 3.87	8.23 ± 6.59	10.56 ± 5.13	9.66 ± 4.09	0.16 (−0.40; 0.73)	−0.30 (−0.89; 0.28)	−0.13 (−0.74; 0.49)	−0.38 (−0.94; 0.16)	−0.25 (−0.82; 0.33)	0.18 (−0.41; 0.79)
1st_60 s	8.29 ± 3.63	6.18 ± 5.94	8.80 ± 4.49	8.38 ± 4.33	0.41 (−0.16; 0.98)	−0.12 (−0.71; 0.46)	−0.02 (−0.64; 0.59)	−0.49 (−1.07; 0.08)	−0.40 (−0.99; 0.17)	0.09 (−0.50; 0.69)
2nd_5 min	6.92 ± 3.92	6.08 ± 4.46	6.50 ± 3.89	7.15 ± 3.27	0.19 (−0.37; 0.76)	0.11 (−0.48; 0.69)	−0.06 (−0.67; 0.55)	−0.10 (−0.64; 0.44)	−0.26 (−0.84; 0.31)	−0.18 (−0.77; 0.42)
2nd_30 s	10.45 ± 6.19	7.63 ± 8.14	8.94 ± 4.81	10.11 ± 7.22	0.37 (−0.20; 0.96)	0.27 (−0.32; 0.87)	0.05 (−0.56; 0.66)	−0.19 (−0.74; 0.35)	−0.31 (−0.89; 0.26)	−0.19 (−0.79; 0.40)
2nd_60 s	9.73 ± 5.58	7.01 ± 7.84	7.88 ± 4.76	8.27 ± 4.75	0.38 (−0.19; 0.96)	0.35 (−0.18; 0.96)	0.27 (−0.34; 0.89)	−0.13 (−0.67; 0.41)	−0.18 (−0.76; 0.39)	−0.08 (−0.68; 0.51)

Data is presented as mean and standard deviation or effect size and 90% confidence intervals. 1st_5 min = first 5–min LnRMSSD; 1st_30 s = first 30 s LnRMSSD; 1st_60 s = first 60 s LnRMSSD; 2nd_5 min = 6–10min LnRMSSD; 2nd_30 s = secondary 30 s LnRMSSD; 2nd_60 s = secondary 60 s LnRMSSD; TC, training camp; ES, effect size.

segments. Moreover, a wide range of ES between trivial and small levels were identified when $LnRMSSD_{cv}$ variable were compared across overseas training camps. It is argued that $LnRMSSD_{mean}$ should be used as a global marker to evaluate the training adaptation of vagal-related activities (Plews et al., 2013b). Whereas, $LnRMSSD_{cv}$ is sensitive to detect the daily variation of ANS adaptation to training workloads and psychophysiological conditions (Nakamura et al., 2020). Our laboratory recently reported that HRV_{UST} of $LnRMSSD_{cv}$ after stabilization period demonstrated large bias and invalid results. In contrast, HRV_{UST} of $LnRMSSD_{mean}$ was valid and reliable to the 5-min standard measure (Chen et al., 2020). However, $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ were only examined in ultra-short-term and standard time segments with/without stabilization in the present study. Nevertheless, trivial to small ES found in all pairwise comparisons indicated the patterns of $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ modulation are similar despite the various objectives of overseas training camps.

Limitations

The findings in the present study were limited by third factors. Firstly, the number of players vary from camps to camps. Longitudinal adaptation in vagal-related changes in relation to periodization was incomparable in this study Secondly, this study did not compare HRV responses to psychometric and physiological markers of training adaptation. Relationship between HRV_{UST} measures and psychophysiological responses during overseas training camps should be established in future studies. Thirdly, time difference and traveling stress within the fourth overseas training camp may have caused a potential bias in the interpretation of the outcome of the studies. Other logistical issues such as the traveling itinerary, accommodation, accessibility of sports facilities, local transportation, and kit management have a critical effect on players' recovery status.

Practical Implication

It is understood that time management is a critical issue within training camps. The players require adequate rest time for recovery from the heavy burden of psychophysiological strains due to congested scheduling (i.e., training sessions, matches, meetings, dining, and additional team activities). These factors are considered when additional prerequisites such as medical checks, psychological consultations, rehabilitation, and training load monitoring are facilitated. The findings of this study suggest that HRV monitoring via HRV_{UST} measures within the first minute could be applied to assess vagal-related changes during training camp.

CONCLUSION

In conclusion, either the first 30 or 60-s LnRMSSD recordings can be used to evaluate daily cardiac-autonomic functions during overseas training camps in futsal players. The process for stabilization seems to be unnecessary for measuring the morning resting LnRMSSD variable during overseas training camps in young adult futsal players. Consideration to use short HRV_{UST} measures should be addressed due to the discrepancies of $LnRMSSD_{cv}$ between time segments. In addition, there is a trivial to small variation of weekly $LnRMSSD_{mean}$ and $LnRMSSD_{cv}$ across different overseas training camps. The observations in our study indicated specific characteristics of HRV modulation in U-20 futsal players during oversea training camps.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Ethics Committee of the University of Taipei. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

Y-SC contributed to the study conceptualization, project administration, investigation, data analysis, methodology, and writing (including reviewing and editing) of the manuscript. JCP and PB contributed to the study conceptualization, data analysis, and writing (including reviewing and editing) of the manuscript. ZC-M contribute to the study data analysis and writing (including reviewing and editing) of the manuscript. C-DK and FMC contributed to the study conceptualization, methodology, supervision, and writing (including reviewing and editing) of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This study was supported by the grant VN99-14 from the Taipei Veterans General Hospital-National Taiwan University Hospital Joint Research Program, Taipei, Taiwan.

ACKNOWLEDGMENTS

The authors would like to thanks the head coach Adil Amarante, team staff, and players of the U-20 Chinese Taipei Futsal team who volunteered for this study.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 12 February 2021
doi: 10.3389/fpsyg.2021.625126

Positional Differences in the Most Demanding Scenarios of External Load Variables in Elite Futsal Matches

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The aims of this study were to analyze the peak physical demands in elite futsal by quantifying the most demanding scenarios of match play and to identify the differences between playing positions (defenders, wingers, and pivots) and the seasonal trend for five different rolling average time windows (30, 60, 120, 180, and 300 s). The most demanding scenarios of external load from distance, speed, acceleration, and deceleration variables were obtained from 14 elite futsal players using a local positioning system during 15 official matches in the premier Spanish Futsal League (2018–2019 season). The results showed an extremely large effect of the time window for all dependent variables in all positional groups. Another important finding of this study was that, in regard to the seasonal trend, only defenders reported clear moderate-large positive trends for high-speed running (>18 km·h^{-1}) efforts, high-acceleration efforts, and high-deceleration efforts. Finally, moderate-large individual differences in player means for all dependent variables and clear differences between games for most dependent variables were found, suggesting how likely contextual factors may exert an influence on how "demanding" the most demanding scenarios are. The findings of this study provide coaches and strength and conditioning coaches further knowledge of the peak physical demands in elite futsal competition. This valuable information may lead to a more precise position-specific training prescription.

Keywords: most demanding scenarios, team sport, game analysis, ultra-wideband, futsal, player monitoring, physical demands

OPEN ACCESS

Edited by:
Bruno Travassos,
University of Beira Interior, Portugal

Reviewed by:
Javier Sánchez-Sánchez,
European University of Madrid, Spain
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Limerick Institute of Technology, Ireland

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *02 November 2020*
Accepted: *15 January 2021*
Published: *12 February 2021*

Citation:
Illa J, Fernandez D, Reche X and Serpiello FR (2021) Positional Differences in the Most Demanding Scenarios of External Load Variables in Elite Futsal Matches. Front. Psychol. 12:625126. doi: 10.3389/fpsyg.2021.625126

INTRODUCTION

Futsal is an intermittent high-intensity indoor team sport involving short, high-intensity actions such as accelerations, decelerations, changes of direction, and sprints with short recovery time between efforts (Yeemin et al., 2016). Competitive matches consist of two 20-min periods characterized by the stoppage of the clock when the ball is out of play resulting in matches usually lasting 70–85% longer than the scheduled 40 min (Barbero-Álvarez et al., 2008). According to its rules, the number of substitutions during futsal matches is unlimited. As in other multidirectional

Abbreviations: UWB, ultra-wideband; MDS, most demanding scenarios; LNFS, Liga Nacional de Fútbol Sala; UEFA, Union of European Football Associations; HSR, high-speed running.

outdoor and indoor team sports, an accurate understanding of the physical demands that players have to face during competition has become increasingly important to inform training program prescription (Gabbett et al., 2012) and periodization to enhance individual and team performance (Akenhead et al., 2016; Aoki et al., 2017) while reducing their susceptibility to non-functional overreaching and likelihood of injury (Bourdon et al., 2017; Fox et al., 2017; Vanrenterghem et al., 2017). Existing research has shown that throughout a competitive season, lower injury rates lead to an increased training and match-play availability of the players which have been associated with improved performance in European Soccer Leagues, International European Cups (Hägglund et al., 2013), and Qatari Professional Football (Eirale et al., 2013).

With the recent availability of wearable microsensor technology and in particular ultra-wideband (UWB) positioning systems in indoor team sports (Serpiello et al., 2018), practitioners have been provided with quantitative data to detect and measure sport-specific movements leading to a greater understanding of the external load demands of the competition (Chambers et al., 2015). Regardless of the team-sport analyzed, most of the studies that focused on defining game activity profiles have used the average of the mean activity performed by the players during competition games (Póvoas et al., 2014; Fox et al., 2018; García et al., 2020; Serrano et al., 2020) without considering the peak physical demands of the competition. For example, in a recent study conducted by Serrano et al., 2020, the influence of the match half and playing position on physical requirements in the Spanish Professional Futsal League was analyzed. Results showed that futsal defenders, pivots, and wingers averaged a relative distance covered per minute of 91 $\pm$ 9, 86 $\pm$ 6, and 95 $\pm$ 10 $m.min^{-1}$, respectively, during the first half and 92 $\pm$ 12, 86 $\pm$ 9, and 92 $\pm$ 9 $m.min^{-1}$, respectively, during the second half. Apparently, these results show some harmony with the playing positions' roles with the pivots being commonly used as a target player during the offensive phase of the game, the defenders commonly marking the pivots in their own territory and wingers performing supporting defensive and offensive runs during the offensive and defensive phases of the game (Ohmuro et al., 2020). Despite this valuable information, this approach may underestimate the most demanding scenarios (MDS) of match play, also referred to as "worst-case scenarios" (Reardon et al., 2017; Cunningham et al., 2018), "most demanding passages" (Martín-García et al., 2018, 2019, 2020; Fernández et al., 2020), and "most intense periods" (Di Mascio and Bradley, 2013).

The MDS have been object of recent investigation in different team sports such as rugby union (Reardon et al., 2017; Cunningham et al., 2018), soccer (Duthie et al., 2018; Martín-García et al., 2018), basketball (Ade et al., 2016; Salazar and Castellano, 2019; Alonso et al., 2020; Fox et al., 2020; Vázquez-Guerrero et al., 2020), and rink hockey (Fernández et al., 2020). To the authors knowledge however, no research has investigated the MDS in futsal.

When analyzing the MDS for any external load variable, researchers have used rolling averages for different time epochs (ranging from 30 s to 10 min) (Whitehead et al., 2018) in an attempt to identify the most appropriate training input when designing and developing training drills (Delaney et al., 2017; Vázquez-Guerrero et al., 2020). Also important from a training prescription standpoint is that MDS have been reported to be position-dependent in soccer (Martín-García et al., 2018) and in basketball (Alonso et al., 2020; Fox et al., 2020; Vázquez-Guerrero et al., 2020).

With all this in mind, the aims of the present study were to (1) examine the peak physical demands during elite futsal competition by quantifying the MDS of match play of different relative (per minute) external load variables and (2) identify the differences between playing positions, between five different time windows and the seasonal trend in the MDS of match play for the different external load variables analyzed.

MATERIALS AND METHODS

Design

A retrospective observational study was undertaken to quantify and analyze the positional differences of the MDS of external load of elite futsal players during 15 official matches of the premier Spanish Futsal League Liga Nacional de Fútbol Sala (LNFS) during the 2018–2019 season. An UWB electronic performance tracking system (WIMU PRO^{TM}, Realtrack Systems, Almeria, Spain) was used to monitor and collect the external load data.

Subjects

Fourteen professional futsal players (age: 28.8 $\pm$ 2.4 years, weight: 73.7 $\pm$ 6.2 kg, height: 175.9 $\pm$ 5.9 cm) from a Spanish elite team that competes in the LNFS and in the Union of European Football Associations (UEFA) Futsal Champions League were monitored using a local positioning system (WIMU Pro, Almeria, Spain). The players were categorized according to their playing positions into defenders (n = 4), wingers (n = 8), and pivots (n = 2). Goalkeepers were not included in this study. Players that played less than 5 minutes during the match or did not complete the match due to an injury were excluded from this study. A total of 143 observations (31 from defenders, 27 from pivots, and 85 from wingers) were collected. All players were routinely monitored throughout the course of the season and were informed of the purpose of the study and provided their written consent before the study was conducted. The experimental procedures used in this study were in accordance with the Declaration of Helsinki and were approved by the local Ethics and Scientific Committee.

Procedures

All the matches were completed on the same official sport-specific indoor court in similar environmental conditions and played during in-season weeks, after a standard 30-min warm-up consisting of dynamic mobility and individual sport-specific skills such as passing, dribbling, and shooting. Although players were continuously monitored during warm-ups and total match time, the MDS were only analyzed when players were competing on court. All data while the players were resting after substitutions and inactivity time between periods were removed.

Data collection was carried out with a local positioning system (WIMU PRO^{TM}, Realtrack Systems SL) and its corresponding software (SPRO^{TM}, Realtrack Systems SL, version 946). The devices were placed in the upper part of the back, in tight-fitting harnesses. The WIMU PRO^{TM} is equipped with four 3D accelerometers (full-scale out output ranges are ± 16 g, ± 16 g, ± 32 g, and ± 400 g; 100 Hz sample frequency), three gyroscopes (8000°/s full-scale out output range; 100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a global positioning system (GPS; 10 Hz sample frequency), and a UWB (18 Hz sample frequency). The UWB system was installed on the court as follows: 6 antennae with UWB technology were fixed 5 m from the court perimeter line. Recently, the WIMU PRO system presented a high intra-class correlation coefficient (ICC) value for the *x*-coordinate (0.65), a very high one for the *y*-coordinate (0.85) and a good technical error of measurement: 2% (Bastida-Castillo et al., 2019).

All the variables selected to describe the external load scenarios were relative to minute. A total of seven variables were analyzed: total relative distance covered ($m \cdot min^{-1}$), high-speed running (HSR) distance (distance covered above 18 $km \cdot h^{-1}$; $m \cdot min^{-1}$), HSR efforts (number of efforts above 18 $km \cdot h^{-1}$; $n \cdot min^{-1}$), high-intensity accelerations efforts (>2 $m \cdot s^{-2}$; $n \cdot min^{-1}$), high-intensity decelerations efforts (<-2 $m \cdot s^{-2}$; $n \cdot min^{-1}$), high-intensity accelerations distance (>2 $m \cdot s^{-2}$; $m \cdot min^{-1}$) and high-intensity decelerations distance (<-2 $m \cdot s^{-2}$; $m \cdot min^{-1}$). A moving average method was used to evaluate the MDS for five different time windows (30, 60, 120, 180, and 300 s), the most used in the bibliography (Whitehead et al., 2018) and the most common time duration on court (the 300-s window) of the players in the analyzed team. The final output database was the maximum point of the rolling average of each game play, for each variable, player, and time window.

Statistical Analysis

To assess the effect of time windows and playing positions, a general mixed linear model was created with Proc Mixed in SAS Studio (University edition, version 9.4, SAS Institute, Cary, NC, United States). The log of each performance indicator was the dependent variable. The fixed effects were: player position (three levels: defender, pivot, and winger), the interaction of player position with the log of the time window (to estimate separate linear effects for each position), and the interaction of player position with the week of the season (to estimate separate linear seasonal trends for each position). The random effects were: player identity (14 levels) and its interaction with the log of the time window (to estimate individual differences in true player means and slopes), with an unstructured covariance matrix to allow their correlation; the game date (15 levels, to allow for differences in game means); and the residuals (with a difference variance allowed for each time window). The seasonal trend was calculated as the predicted mean at the end of the season minus the predicted mean at the beginning of the season. The magnitude of the effect of the time window was calculated as the predicted mean for the 30-s window minus the predicted mean for the 300-s window. Effects and standard deviations were back-transformed to percent units. Differences between playing position groups within each time window were not assessed due to the limited sample size. Uncertainty in the estimates of effects is presented as 90% compatibility limits. Probabilistic decisions about true (infinite-sample) magnitudes accounting for the uncertainty were based on one-sided hypothesis tests of substantial magnitudes (Lakens et al., 2018). The *p*-value for rejecting a hypothesis of a given magnitude was the area of the sampling *t* distribution of the effect statistic with values of that magnitude. Hypotheses of substantial decrease and increase were rejected if their respective *p*-values were less than 0.05. If one hypothesis was rejected, the *p*-value for the other hypothesis was interpreted as evidence *for* that hypothesis, since the *p*-value corresponds to the posterior probability of the magnitude of the true effect in a reference Bayesian analysis with a minimally informative prior (Hopkins and Batterham, 2018, 2019). The *p*-value is reported qualitatively using the following scale: 0.25–0.75, possibly; 0.75–0.95, likely; 0.95–0.995, very likely; > 0.995, most likely (Hopkins et al., 2009). If neither hypothesis was rejected, the magnitude of the effect was considered to be unclear. Effects with sufficient probability of a magnitude (at least very likely) were deemed clear.

RESULTS

Descriptive statistics of the raw data for all time windows and playing positions are reported in **Table 1**. Overall, the analyzed time windows for the MDS of all variables displayed the typical trend of a power law which has been previously identified in similar research studies in other sports (Duthie et al., 2018). There was a clear, extremely large effect of the time window for all dependent variables in all positional groups (**Table 2**). The analysis of the seasonal trend (i.e., as the predicted mean of each variable at the end of the season minus the predicted mean at the beginning of the season) returned varied results, with some unclear effects and some clear effects of moderate to large magnitudes (**Table 2**).

The analysis of the random effects showed clear, moderate-large individual differences in player means for all dependent variables, unclear differences in the slopes (i.e., the individual slopes representing the effect of the time windows), and clear small-moderate differences in game means (**Table 3**).

DISCUSSION

The present study was designed to determine the positional differences along with the seasonal trend in the peak physical demands of elite futsal competition by quantifying the MDS of match play of different relative (per minute) external load variables between five different time windows in elite futsal competition. With respect to the initial objective of this study, it was found that peak physical demands during elite futsal competition are position-dependent for all time windows analyzed. Additionally, moderate-large individual differences in player means for all dependent variables and clear differences between games for most dependent variables were found. Another major finding of this study was that seasonal trends are also position and variable-dependent.

TABLE 1 | Descriptive statistics for the most demanding scenarios of each dependent variable assessed across five time windows.

		Time window (s)				
		30	**60**	**120**	**180**	**300**
Relative distance (m.min^{-1})	Defenders	186 ± 14	155 ± 10	133 ± 8	123 ± 7	112 ± 9
	Pivots	175 ± 15	143 ± 12	124 ± 11	115 ± 10	105 ± 9
	Wingers	187 ± 17	154 ± 14	132 ± 11	122 ± 10	113 ± 8
Distance HSR (m.min^{-1})	Defenders	47 ± 14	27 ± 8	16 ± 5	12 ± 4	8 ± 3
	Pivots	43 ± 14	24 ± 7	15 ± 6	10 ± 4	7 ± 3
	Wingers	54 ± 17	32 ± 11	20 ± 7	15 ± 5	11 ± 4
HSR efforts (n.min^{-1})	Defenders	4.5 ± 1.4	2.8 ± 0.8	1.7 ± 0.5	1.4 ± 0.4	1.0 ± 0.3
	Pivots	3.9 ± 1.4	2.4 ± 0.8	1.4 ± 0.5	1.1 ± 0.4	0.8 ± 0.3
	Wingers	4.8 ± 1.4	3.0 ± 0.9	1.9 ± 0.7	1.5 ± 0.5	1.1 ± 0.4
High accelerations distance (m.min^{-1})	Defenders	75 ± 13	52 ± 8	39 ± 6	34 ± 5	28 ± 4
	Pivots	65 ± 9	44 ± 5	31 ± 5	27 ± 4	22 ± 3
	Wingers	78 ± 14	52 ± 9	39 ± 8	33 ± 7	27 ± 6
High accelerations efforts (n.min^{-1})	Defenders	13.9 ± 2.0	10.5 ± 1.8	7.8 ± 1.3	6.7 ± 1.2	5.7 ± 1.0
	Pivots	11.8 ± 1.9	8.1 ± 1.2	5.9 ± 0.7	5.1 ± 0.6	4.3 ± 0.5
	Wingers	13.9 ± 2.3	9.9 ± 2.0	7.5 ± 1.5	6.5 ± 1.2	5.4 ± 0.9
High decelerations distance (m.min^{-1})	Defenders	66 ± 12	45 ± 7	33 ± 4	28 ± 4	23 ± 4
	Pivots	63 ± 13	42 ± 7	30 ± 5	24 ± 4	20 ± 3
	Wingers	69 ± 13	47 ± 9	34 ± 7	28 ± 6	24 ± 5
High decelerations efforts (n.min^{-1})	Defenders	14.4 ± 2.4	10.1 ± 2.1	7.5 ± 1.7	6.5 ± 1.4	5.4 ± 1.1
	Pivots	11.6 ± 2.0	8.0 ± 1.1	6.0 ± 0.7	5.0 ± 0.5	4.2 ± 0.5
	Wingers	13.7 ± 2.4	9.6 ± 1.7	7.2 ± 1.4	6.3 ± 1.2	5.2 ± 1.0

Data presented as mean ± SD.
Number of players = 14 (4 Defenders, 2 Pivots, 8 Wingers); Number of observations = 143 (31 for Defenders, 27 for Pivots, 85 for Wingers); Number of games = 15.
HSR, high-speed running.

TABLE 2 | Fixed effects representing the effect of time window and the seasonal trend on all dependent variables for the three positional groups.

		Time window 30/300	Seasonal trend
Relative distance	Defenders	65 ± 6%; ext.large***	−3.2 ± 3.9%; small
	Pivots	64 ± 8%; ext.large***	−3.2 ± 3.9%; small*
	Wingers	65 ± 4%; ext.large***	2.3 ± 3.3%; unclear
Distance HSR	Defenders	483 ± 74%; ext.large***	12 ± 37%; unclear
	Pivots	505 ± 91%; ext.large***	2.6 ± 21%; unclear
	Wingers	402 ± 41%; ext.large***	−25 ± 13%; small**
HSR efforts	Defenders	377 ± 63%; ext.large***	31 ± 26%; moderate**
	Pivots	409 ± 84%; ext.large***	17 ± 23%; small*
	Wingers	329 ± 37%; ext.large***	−12 ± 15%; small
High accelerations distance	Defenders	166 ± 17%; ext.large***	3.9 ± 7.7%; unclear
	Pivots	196 ± 24%; ext.large***	14 ± 8%; moderate**
	Wingers	184 ± 12%; ext.large***	0.6 ± 5.4%; unclear
High accelerations efforts	Defenders	151 ± 12%; ext.large***	32 ± 12%; large***
	Pivots	171 ± 14%; ext.large***	13 ± 10%; moderate*
	Wingers	155 ± 7%; ext.large***	13 ± 9%; moderate**
High decelerations distance	Defenders	187 ± 17%; ext.large***	3.1 ± 9.7%; unclear
	Pivots	210 ± 23%; ext.large***	3.3 ± 9.7%; unclear
	Wingers	197 ± 11%; ext.large***	−6.5 ± 7.3%; small*
High decelerations efforts	Defenders	167 ± 16%; ext.large***	35 ± 15%; large***
	Pivots	171 ± 20%; ext.large***	16 ± 13%; moderate**
	Wingers	164 ± 10%; ext.large***	−1.0 ± 9.4%; unclear

Data presented as percent effects ± 90% compatibility interval, with magnitude decision.
Time window 30/300 = predicted mean for the 30-s window minus the predicted mean for the 300-s window; Seasonal trend = predicted mean at the end of the season minus the predicted mean at the beginning of the season.
*HSR, high-speed running. * = Likely, ** = very likely, and *** = most likely substantial effect.*

TABLE 3 | Random effects (standard deviations) representing individual differences in player means and slopes, and differences in game means.

	Intercept	Time window 30/300	Date
Relative distance	5.7 ± 2.3%; large**	2.3 ± 3.2%; unclear	2.0 ± 0.9%; small**
Distance HSR	23 ± 10%; moderate**	4.5 ± 11%; unclear	11 ± 5%; small**
HSR efforts	19 ± 8%; moderate**	7.0 ± 12%; unclear	11 ± 5%; moderate**
High accelerations distance	12 ± 5%; large**	3.7 ± 5.4%; unclear	2.9 ± 1.8%; small*
High accelerations efforts	12 ± 5%; large**	−3.0 ± 3.2%; unclear	4.9 ± 2.1%; small**
High decelerations distance	11 ± 5%; large**	2.2 ± 5.0%; unclear	4.9 ± 2.1%; small**
High decelerations efforts	11 ± 5%; large**	2.1 ± 5.1%; unclear	6.4 ± 2.6%; moderate**

Data presented as standard deviation Ī' 90% compatibility interval, with magnitude-based decision.
Intercept = individual differences in player true means; Time window 30/300 = predicted mean for the 30-s window minus the predicted mean for the 300-s window; Date = differences in game means after removing seasonal trend.
*HSR, high-speed running. * = Likely, ** = very likely.*

Our study highlights some interesting results related to both the fixed and random effects. There was a clear, extremely large effect of the time window for all dependent variables in all positional groups (**Table 2**). Interestingly, relative distance was the dependent variable with the smallest difference between the 30-s and 300-s window (∼65% for all groups), while the HSR distance (∼400-500%) and HSR efforts (∼330-410%) were the dependent variables with the largest differences. These results have important practical applications for training design, as they reflect the importance of knowing to what extent the different physical output targets must be adjusted in relation to the duration of a training drill. For example, for a same given drill performed either as 10 × 30-s repetitions or one whole 300-s exercise, the target for relative distance for the defenders would need to be ∼930 m in each 30-s repetition and ∼560 m for the 300-s drill. Conversely, the high-speed running distance would decrease from ∼235 efforts to ∼40.

Positional differences in the MDS of match play have been previously reported in different team-sports such as football (Hopkins et al., 2009), basketball (Vázquez-Guerrero et al., 2020), and rink hockey (Fernández et al., 2020). It is worth discussing that even though differences between playing position groups within each time window were not assessed due to the limited sample size, the results of this study suggest that peak physical demands are "higher" for defenders and wingers than for pivots for all variables analyzed. In accordance with these results, a previous study conducted by Serrano et al., 2020 reported similar patterns when describing differences across playing positions by evaluating the physical demands of official futsal matches through the traditional approach based on average values. It is possible to hypothesize that these differences may be attributed to the nature of each specific playing-position role with its particular technical and tactical requirements during the offensive (López, 2017; Méndez et al., 2019; Ohmuro et al., 2020) and the defensive phase of the game (López, 2017; Ohmuro et al., 2020). In contrast with the differences found with the pivots, our results showed similar values of the MDS in all dependent variables for defenders and wingers which could be explained by the continuous exchangeability that both playing-positions perform during games (Caetano et al., 2015; Serrano et al., 2020). This combination of findings provides some important support for training prescription, especially when attending to individualized training and rehabilitation programs and return-to-play protocols after injury (Vázquez-Guerrero et al., 2020).

To the best of the authors' knowledge, this is the first study in elite futsal to compare the MDS of match play across different positions and time windows. However, comparisons of our results with those of other studies performed in other team sports (Martín-García et al., 2018; Salazar and Castellano, 2019; Fernández et al., 2020; Vázquez-Guerrero et al., 2020) reveal some interesting findings. During the MDS of match play, futsal players cover less distance than football players regardless of the position for the 60-, 180-, and 300-s time windows (Martín-García et al., 2018) but more than basketball players (Salazar and Castellano, 2019; Vázquez-Guerrero et al., 2020) only for the 180- and 300-s time windows. A possible explanation for these differences could be the larger playing area of the football field (100 m long and 80 m wide) compared to the futsal and the basketball courts (40 and 28 m long; 20 and 15 m wide respectively). Besides, futsal players cover a lower amount of HSR distance during the MDS of match play than rink hockey players (Fernández et al., 2020) but greater than basketball players in all positions and time windows (Vázquez-Guerrero et al., 2020). It seems important to recall the fact that rink hockey players do not run but rather skate, which may explain the large difference found in these results. Another interesting finding is that futsal players cover higher volume of high intensity acceleration and deceleration distance and perform a greater number of high intensity accelerations and decelerations than basketball players for all positions and time windows. The reason for such differences is not clear but it may be related to the idiosyncrasy of the short stoppages and interruptions during futsal matches (i.e., outsides, corner-kicks) in which players continue to move even when the ball is not in play (Illa et al., 2020).

The results regarding the seasonal trends also have important practical applications. While most trends were unclear or only likely substantial and small in magnitude, some clear moderate-large trends were identified. For example, defenders were the only positional group to report clear moderate-large positive trends for HSR efforts, high-acceleration efforts, and high-deceleration efforts. On the other side, wingers reported small decrements in HSR distance. These results may be influenced by contextual factors such as the strength of the opposition; however, this cannot be speculated upon without further investigation.

As mentioned in the results section, the analysis of the random effects returned clear, moderate-large individual differences in player means for all dependent variables; this signifies that independent of the playing position, players differ overall in how "demanding" the MDS are for all variables. This information, in conjunction with the information regarding the positional differences and the seasonal trends, can assist the practitioner to further individualize the training prescription. Similarly, clear differences were found between games for most dependent variables; this difference again points to the likely influence of contextual factors on the MDS, but it also provides practical information to further modify the game preparation. Further research should be undertaken to investigate the influence of the contextual factors in the magnitude of the match-to-match variability of the MDS of match play in elite futsal competition.

CONCLUSION

One of the most significant findings to emerge from this study is the extremely large effect of the time window for all dependent variables in all positional groups. This study has also identified clear differences between games for most dependent variables and moderate-large individual differences in player means for all dependent variables alongside with clear moderate-large positive trends for high-speed running (>18 km·h^{-1}) efforts, high-acceleration efforts, and high-deceleration efforts for defenders. With these results, practitioners are provided with some insight regarding to the MDS of match play which may lead to a more precise position-specific training prescription. Evidently peak physical demands of elite futsal competition are very high, and therefore, players' training program prescription should be properly designed to prepare players for such high demanding exposures. However, practitioners are advised to consider individual variability when attending to positional requirements and adapting these scenarios to the duration of the training drills.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Comitè d'Ètica d'Investigacions Clíniques de l'Administració Esportiva de Catalunya. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JI contributed to the conception and design of the study, contributed to the data collection and interpretation of results, and contributed to the manuscript writing. DF participated in the design of the study, contributed to the data reduction/analysis and interpretation of results, and contributed to the manuscript writing. FS participated in the design of the study, contributed to the data reduction/analysis and interpretation of results, and contributed to the manuscript writing. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

ACKNOWLEDGMENTS

The authors gratefully acknowledge to all elite players who participated in the study. The authors also would like to thank all the members of the sports performance area of FC Barcelona for their valuable contribution to this study, as well as the support of the FC Barcelona Innovation Hub. The authors would also like to thank Prof. Will Hopkins from the Institute for Health and Sport (IHES), Victoria University, for his contribution toward the statistical analysis.

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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.

ORIGINAL RESEARCH
published: 01 April 2021
doi: 10.3389/fpsyg.2021.578332

Identification of the Patterns Produced in the Offensive Sequences That End in a Goal in European Futsal

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Victory is the ultimate aim in high performance sports; when it comes to team sports, the goal is the key that allows players to achieve that victory. This is the case with futsal which, due to its internal structure as well as the speed in the development of its game, makes the achievement of a goal not an isolated event, but rather more than one goal must be scored to achieve victory. The aim of the present study is to analyze the construction of offensive sequences that have resulted in goal-scoring in the two main European futsal leagues, the Spanish and the Italian, as well as to identify the patterns relating to offensive actions that have ended with a goal being scored. Observational methodology was used to develop the research and an *ad hoc* observation instrument (OAF-I) was developed for this purpose. The data was analyzed using inferential statistics as well as sequential analysis of delays in a diachronic analysis to identify the patterns of offensive actions. The results obtained enable recognition of a league's idiosyncrasy patterns in goal-scoring in each of the leagues studied. The results obtained will allow experts to have a better understanding of how goals are scored and how to establish more specific training tasks, in both attack and defense.

Keywords: performance analysis, observational methodology, futsal, lag sequential analysis, goal

Edited by:
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Reviewed by:
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *30 June 2020*
Accepted: *09 March 2021*
Published: *01 April 2021*

Citation:
Amatria M, Álvarez J, Ramírez J and Murillo V (2021) Identification of the Patterns Produced in the Offensive Sequences That End in a Goal in European Futsal. Front. Psychol. 12:578332. doi: 10.3389/fpsyg.2021.578332

INTRODUCTION

The attack-defense duel is the essence of team sports (Garganta, 2009), where game systems are defined as the base structures representing the way in which players, as well as the functions to be developed, are distributed across the playing field, determining the offensive and defensive attitude of the players and the team (Pascual et al., 2019). That offensive or defensive attitude is extremely closely linked to the playing system used, a fact that gives rise to the team's efficiency, which is improved by incorporating functions into the playing system (Mutti, 2003; Saraiva, 2010).

How effective a team is, in both collective sports in general and futsal in particular, is shown by the number of victories achieved (Amatria et al., 2019), which will ultimately depend on the final result of the match, obtained through the difference between goals scored and goals conceded, the goal being the most relevant indicator and predictor of performance in this sport (Schneider et al., 2015; Agras et al., 2016; Álvarez et al., 2018; Gómez et al., 2018).

As futsal is considered a low-scoring sport (Reina and Hernández-Mendo, 2012), the relevance of the goal as a performance indicator, as well as the analysis of the competition, acquire greater importance (Abdel-Hakim, 2014). This factor is especially admissible in regard to competition and high-level teams as the pressing professionalism and demand at every physiological, physical, technical-tactical, and psychological level increases equality amongst competitors (Álvarez et al., 2002, 2004).

For that reason, the study, analysis, and knowledge of the goal has generated a great deal scientific interest, despite the need for greater research into this sport (Cachón et al., 2012; Ramírez, 2015). The largest amount of research in that regard focuses on quantitative aspects (Hristovski et al., 2017), which is why the following questions arise: what circumstances need to take place in the development of the offensive action in order for the goal to be scored and what behaviors are repeated to achieve that? In this respect, the research community has shown growing interest in responding to how the offensive game develops and in trying to identify common behavioral patterns that are produced and replicated during particular attack sequences (Lapresa et al., 2013; Sarmento et al., 2016) in such a way that the repetition of behavior appears over time and favors their predictable recurrence (James, 2012).

Recognizing the behavioral patterns that occur in the development of the game and the means by which the goal is achieved (type of play, technical-tactical actions, etc.) is vital in optimizing the training process and in obtaining an advantage in competitive matches (James, 2012). For that reason, the determining aspect has begun to be valued, and there are several studies that provide relevant data and that are focused on analyzing offensive actions (Barbero, 2003; Irokawa et al., 2010; Travassos et al., 2011; Leite, 2012; Lapresa et al., 2013; Pascual et al., 2019). The following researchers focus on the world's greatest leagues (Méndez et al., 2019), the Spanish and Italian leagues, which were the two greatest professional futsal leagues from 1996 to 2015 (Göral, 2018).

This study has a double objective: to analyze and identify the types of plays relating to the offensive sequences resulting in a goal in the two main European indoor football leagues, the Spanish and Italian leagues, during the 2014–2015 season; and to identify and compare behavior patterns relating to the offensive actions that result in a goal in both leagues during this competition.

MATERIALS AND METHODS

This study was carried out using observational methodology (Anguera, 1979), which found in the sport an ideal space for its implementation (O'Donoghue, 2009; McGarry et al., 2013; Anguera and Hernández-Mendo, 2015).

The design of the research has been carried out following the design of Anguera et al. (2011) and is of type N/D/M: nomothetic, datable (intra-sessional and inter-sessional), and multidimensional.

Participants

To further develop our research, all of the goals scored in the 2014–2015 season from the two best professional futsal leagues in the 1996–2015 period (Göral, 2018) were taken as a sample (those being the Italian and Spanish leagues).

Videos of the goals were obtained by getting access to entire match footage, or to summaries in instances where footage could not be obtained from the various organizing bodies of the competitions, teams (the totality of matches corresponding to the Spanish league -240 matches-, and 83 to the Italian league), and open platforms (27 matches corresponding to the Italian league). At all times, entire match footage was taken as the first visual source; when such footage was unavailable, summaries were used.

The sample consisted of 5,145 multi-events, which gave rise to a total of 735 goals scored in the 110 matches that made up the regular Italian championship. The sample also consisted of 12,285 multi-events that gave rise to the 1,755 goals scored in 240 Spanish league matches, giving a total sample of 17,430 multi-events.

Observational Instrument

The Observational Analysis of Futsal's (OAF-I) observation instrument (Álvarez et al., in press) was used (see **Table 1**), being made up of the combination of category systems, meeting the requirements of exhaustive and mutually exclusive field formats (Anguera and Hernández-Mendo, 2013), the former being nested in the latter (Anguera et al., 2007).

Registration and Coding

The data was recorded using Lince software, version 1.2.1 (Gabin et al., 2012). The recording of each sequence was structured in three stages: a first stage, called observation, in which the offensive action was initially viewed in full without anything being noted; a second stage, in which the offensive action was viewed a second time along with the recording of the sequence itself, which, in turn, was carried out in three separate phases—the beginning of the offensive sequence, in which the categories corresponding to the Previous Result, Position, Starting Zone, and Starting Form dimensions were recorded; the development of the sequence, in which the categories corresponding to the Type of Play, Players involved, and Number of passes dimensions were recorded; and, finally, the end of the sequence, in which the categories corresponding to the rest of the dimensions were recorded (**Figure 1**). The last stage of the record consisted of viewing the action one last time to corroborate the data recorded in the previous stage. The recording unit ends when the team under observation scores the goal. The data analyzed are concurrent and event-based (Bakeman, 1978).

According to Lapresa et al. (2013), Álvarez (2015), Amatria (2015), and Ramírez (2015) in futsal, and Casal et al. (2017) in soccer, the team under observation is interpreted as being in possession of the ball when at least one of the following three action situations occurs: (a) the player who receives the ball makes at least two contacts with it; (b) a player intercepts the ball and then a team mate continues the action; or (c) a player takes a throw-in in a set piece action.

Data Reliability

The data was recorded by two observers, Physical Activity and Sports Sciences and National Futsal Coach graduates with more

TABLE 1 | Observation instrument.

Dimension	Category systems: codes and brief description
Player no.	1, 2, 3, 4, 5, 6, ...
League	ITA) Italian; SP) Spanish; RUS) Russian
Move	R1) 1st round of matches; R2) 2nd round of matches; R3) 3rd round of matches; R4) 4th round of matches; R5) 5th round of matches; R6) 6th round of matches; R7) 7th round of matches; R8) 8th round of matches; R9) 9th round of matches; R10) 10th round of matches; R11) 11th round of matches; R12) 12th round of matches; R13) 13th round of matches; R14) 14th round of matches; R15) 15th round of matches; R16) 16th round of matches; R17) 17th round of matches; R18) 18th round of matches; R19) 19th round of matches; R20) 20th round of matches; R21) 21st round of matches; R22) 22nd round of matches; R23) 23rd round of matches; R24) 24th round of matches; R25) 25th round of matches; R26) 26th round of matches; R27) 27th round of matches; R28) 28th round of matches; R29) 29th round of matches; R30) 30th round of matches
Round	RO1) round 1; RO2) round 2
Venue	LOC) local; AWA) away
Player position	GK) goalkeeper; WIN) winger; PIV) pivot; UNI) universal
Starting area	SA10) starting area 10; SA11) starting area 11; SA11a) starting area 11a; SA12) starting area 12; SA12a) starting area 12a; SA13) starting area 13; SA13a) starting area 13a; SA14) starting area 14—defensive areas -; SA20) starting area 20; SA21) starting area 21; SA22) starting area 22; SA23) starting area 23; SA24) starting area 24—creation area own pitch -, SA40) starting area 40, SA41) starting area 41; SA42) starting area 42; SA43) starting area 43; SA44) starting area 44—creation areas away pitch -; SA50) starting area 50; SA51) starting area 51; SA51a) starting area 51a; SA52) starting area 52; SA52a) starting area 52a; SA53) starting area 53; SA53a) starting area 53a; SA54) starting area 54—offensive areas -. View **Figure 2**
Ending area	EA10) ending area 10; EA11) ending area 11; EA11a) ending area 11a; EA12) ending area 12; EA12a) ending area 12a; EA13) ending area 13; EA13a) ending area 13a; EA14) ending area 14—defensive areas -; EA20) ending area 20; EA21) ending area 21; EA22) ending area 22; EA23) ending area 23; EA24) ending area 24—creation area own pitch -, EA40) ending area 40; EA41) ending area 41; EA42) ending area 42; EA43) ending area 43; EA44) ending area 44—creation areas away pitch -; EA50) ending area 50; EA51) ending area 51; EA51a) ending area 51a; EA52) ending area 52; EA52a) ending area 52a; EA53) ending area 53; EA53a) ending area 53a; EA54) ending area 54—offensive areas -. View **Figure 2**
Beginning	ROB) steal of the player; PI) Pass interception; PRS) pressure; CLEAR) clearance; MOV) move; REB) rebound; PLY) play; ANOT1) another; GK) goal kick; TI) throw in; CK) corner kick; DFK) direct free kick; IFK) indirect free kick; PE) penalty; DP) double penalty; MK) midfield kick; DB) dropped ball
Type of move	PA) positional attack (attack against organized defense developed in a sustained way); CA) counterattack (rapid attack after theft developed with the fewest possible passes and disorganized defense); CFG) counterattack in front of fly goalkeeper; PD) pressuring defense; FG) fly goalkeeper; SUP) superiority INF) inferiority: SP) Set pieces; ANOT2) another
Players on the pitch	PL1) 1 player; PL2) 2 players; PL3) 3 players; PL4) 4 players; PL5) 5 players
Number of passes	PS0) 0 passes; PS1) 1 pass; PS2) 2 passes; PS3) 3 passes; PS4) 4 passes; PS5) 5 passes; PS6) 6 passes; PS7) 7 passes; PS8) 8 passes; PS9) 9 passes; PS10) 10 passes; PS100) 11 or more passes
Ending of the game	DRB) dribbling; SR) short running; LR) long running; REB) rebound; DET) detour; 2FP) 2nd far post; OTP) one-two with pivot; OVL) overlap run; PM) pass to the midfield; OG) own goal; NON) none; ANOT3) another
Number of touches	TO1) 1 touch; TO2) 2 touches; TO3) 3 touches; TO4) 4 touches; TO5) 5 touches; TO6) 6 touches; TO7) 7 touches; TO8) 8 touches; TO9) 9 touches; TO10) 10 touches; TO100) 11 or more touches
Contact area	RIN) right instep; LIN) left instep; RINT) right interior; LINI) left interior; EXR) external right; EXL) left external; RT) right toecap; LT) Left toecap; RH) right heel; LH) left heel; HEAD) head; ANOT4) another
Penalty area	LS) low shot; RS) raised shot; HS) high shot
Laterality of the penalty area	RIGHT) right; LEFT) left; MIDD) middle
Time of goal	P11) 0′–5′ 1st half; P12) 6′–10′ 1st half; P13) 11′–15′ 1st half; P14) 16′–20′ 1st half; P21) 0′–5′ 2nd half; P22) 6′–10′ 2nd half; P23) 11–15′ 2nd half; P24) 16–20′ 2nd half.
Prior result	RV) victory; RT) draw-tie; RD) defeat
Temporary home scorer	It shows the temporary score: from 0 to 15, coinciding the value of the parameter with the number of goals scored by the home team.
Temporary away scorer	It shows the temporary score: from 0 to 15, coinciding the value of the parameter with the number of goals scored by the away team
Difference of goals	It shows the difference of goals between the teams, which means the goal scored. From 15 to -15, being 15 the maximum difference of goals in favor of the home team and -15, the maximum one in favor of the away team; 0 means draw
First result, halftime, and final result	FRFG) First result—first goal; FRFGRH) First result- first goal and result at the halftime; FRFGFHFR) First result—First goal, result at the halftime and final result; FGFRFR) First goal—First result and final result; RH) result at the halftime; RHFR) Result at the halftime and final result; FR) final result
Classification of round of matches	Classification with which the observed team begins the round of matches. From 1 to 16, being 1 the first position and so on
Final classification	Classification with which the observed team ends the league. From 1 to 16, 1 being the first position and so on

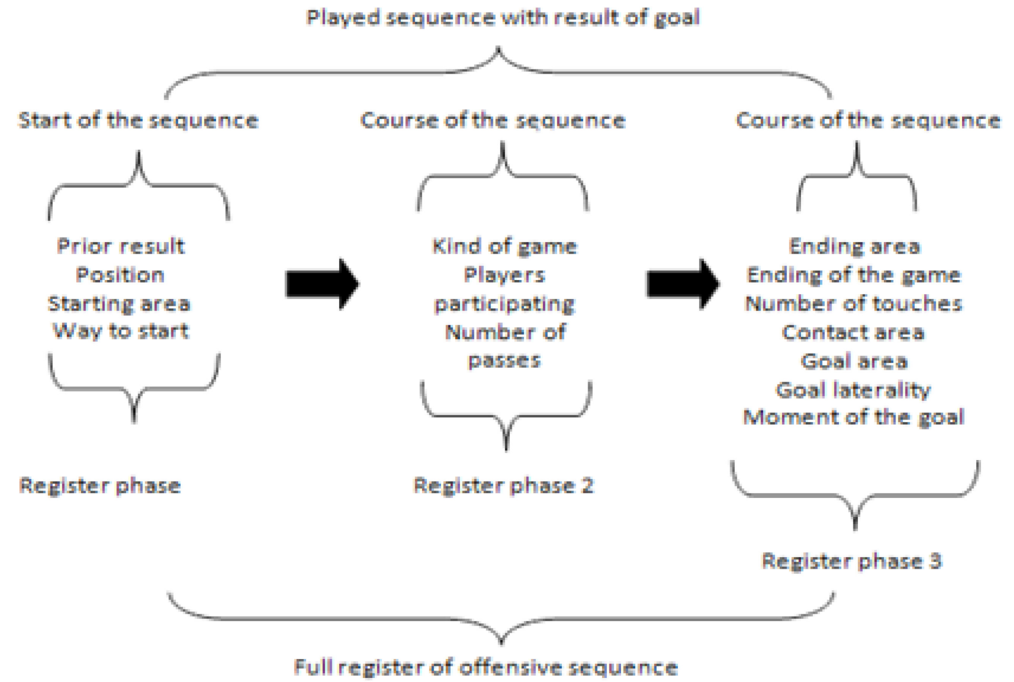

FIGURE 1 | Structure of the recording of each play resulting in a goal: phases and dimensions to record.

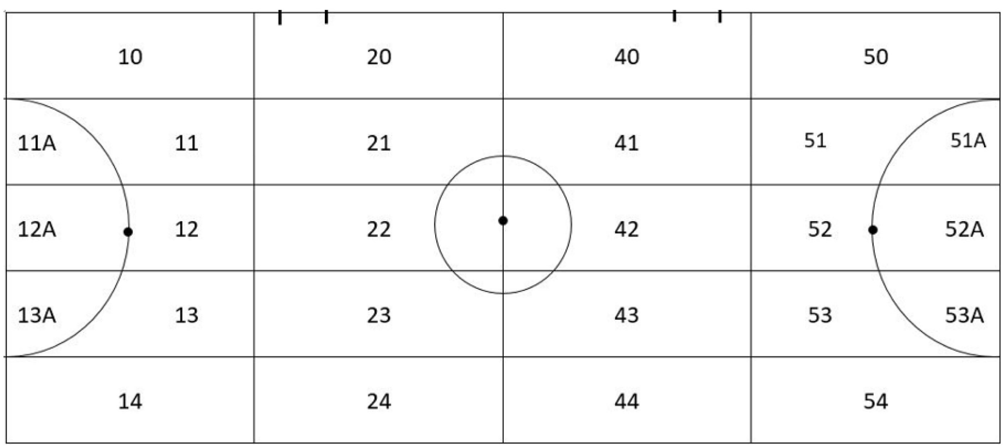

FIGURE 2 | Field graph of spatial distribution according to the zones of the game.

than 5 years' experience in physical training and coaching in elite teams and observational methodology, who previously carried out a training process based on Anguera (2003). The first observer created data set 1 by recording samples on two occasions: the first, collecting all samples; and the second, collecting 10% of the total (inter-observer agreement). The second observer created a third record (intra-observer agreement) obtained on a consultative basis (Arana, 2011; Arana et al., 2016).

In order to determine the reliability (in the form of concordance) of the data obtained from the observation instrument, Cohen's kappa coefficient (Cohen, 1960) was used throughout the GSEQ program (Bakeman and Quera, 2011), version 5.1. The Cohen's kappa coefficient values corresponding to the data packages recorded by both observers have been calculated by dimensions or criteria of the observation instrument, giving a minimum value of $\kappa > 0.9$ and agreement >95% (**Table 2**), which corresponds, in line with the values determined by Landis and Koch (1977), to an *"almost perfect."*

The data was analyzed using the two types of analysis that make up mixed methods, i.e., quantitative analysis and qualitative analysis (Anguera et al., 2014).

In order to respond to the first of these objectives and to analyze and identify the types of plays corresponding to

TABLE 2 | Cohen's Kappa results of first and second observer for each of the leagues analyzed, by dimensions.

	Spanish league	Italian league
Dimension	Kappa value	Kappa value
Player no.	1	1
League	1	1
Move	1	1
Round	1	1
Venue	1	1
Player position	0.96	0.92
Start area	0.9	0.93
Ending area	0.92	0.9
Beginning	0.91	0.95
Type of move	0.95	0.91
Players on the pitch	0.93	0.95
Number of passes	0.94	0.96
Ending of the game	0.91	0.93
Number of touches	0.97	0.98
Contact area	0.98	0.97
Penalty area	0.97	0.98
Laterality of the penalty area	0.91	0.96
Time of goal	1	1
Prior result	1	1
Temporary home scorer	1	1
Temporary away scorer	1	1
Difference of goals	1	1
First result, halftime, and final result	1	1
Classification of round of matches	1	1
Final classification	1	1

the offensive sequences ending in goals, a crossover analysis between leagues was carried out, establishing three pairs of categorical variables that, due to their internal relationships, are relevant for the study. Firstly, the PA (positional attack) and CA (counterattack) pair have been established because they are attacks against structured and unstructured defenses. The second established pair comprises the FG (fly goalkeeper) and the CAFG (counterattack against the fly goalkeeper), in relation to the goals achieved during this particular facet of the sport. Finally, a third pair of relevant categories has been established, corresponding to the SP (set piece) category and to the remaining moves, as they are played standing in front of the those that occur in motion.

For the data analysis of those three pairs, analysis was done by searching for associative relationships between categorical variables. For this, the parametric Pearson chi-square test (χ χ2) was adopted using the following formula (Carro et al., 1997), $\chi^2 = \sum_{i=1}^{I} \sum_{j=1}^{J} \frac{(fe_{ij} - ft_{ij})^2}{ft_{ij}}$, establishing a statistical significance relationship between variables analyzed when $p < 0.05$.

A diachronic analysis of the data was done at a qualitative level to meet the second objective of this study: identifying the goal pattern in the Spanish and Italian leagues. Specifically, sequential-delay analysis was carried out (Sackett, 1980), which allows for the identification of behavioral patterns understood as "behaviors that occur with greater cohesion than mere chance" (Anguera, 1990, p. 202).

To carry out the calculation, a behavior from within the categorical lag data was taken as the initial hypothesis (core behavior). The lag number indicates the order in which it occurs.

Once the conditional behaviors and lags of interest have been defined, a matching frequencies table based on the given behavior is generated (Sackett, 1987). That table can be used to observe the positive behaviors (when conditional probabilities are greater than the expected) and lay down every link in the behavior pattern at each lag (Anguera et al., in press).

This can be applied to any research situation in which categorical actions are measured in an ordered sequence of actions or time (Castellano, 2000). Doing so establishes the suitability of the technique for data analysis, since it makes use of the capacity of the observational methodology to capture behaviors that develop according to parameters of order and duration (Anguera et al., 2000). Using the GSEQ software, v 5.1 (Bakeman and Quera, 2011), the adjusted residuals have been calculated between the behavior criterion corresponding to the League dimension and the conditioned behaviors corresponding to the rest of the dimensions that make up the instrument (player position, play start zone, play end zone, play start form, type of play, players involved, number of passes, play end, number of touches, contact surface, goal zone, goal laterality, time of goal, and previous result). Conditioned behaviors have been analyzed prospectively in relation to the established criteria categories, from co-occurrence 0 to delay 6.

In order to test the existence of a statistical association between conditional and expected behavior, a binomial formula can be applied (Anguera, 1990):

$$z = \frac{P_{Observed} - P_{expected}}{\sigma_{expected}} \quad (1)$$

where

$$\sigma_{expected} = \sqrt{\frac{P_{observed}(1 - P_{expected}}{N_{Crit}}} \quad (2)$$

and with $N_{Crit.}$ being the total core behavior appearances.

According to Bakeman and Gottman (1987) and Arias-Pujol and Anguera (2020), transitions greater than 1.96 show a statistically significant relationship ($p < 0.05$) of activation between the given behavior and the target behavior; transitions smaller than −1.96 indicate a statistically significant relationship of inhibition between the behavior criterion and the conditioned behavior.

RESULTS

Presented below are the results obtained from analysis of the type of play in which the goal is scored during the competitions examined. For further clarification of the results, three analysis sections are presented, taking into account the typological pairs of established moves.

In **Table 3**, it can be seen how, of the 1,719 goals scored in the Spanish league during the 2014–2015 season, the types of play through which the goal is scored are instigated from positional attack (PA), with 27.7% of the total, followed by counterattack (CA), with 26.8%, and set piece (SP), with 24%. On the other hand, of the 695 goals scored in the Italian league in the same season, the highest percentage (26%) relates to set piece (SP), followed by 24.2% from counterattack plays and, finally, positional attack (PA), with 23.3%.

Table 4 shows the results obtained by the chi-squared test corresponding to the first pair of established moves (PA-CA), where no significant results are seen between those categories. Considering the analysis of the chi-squared tests corresponding to the second established pair (FG-CAFG), **Table 4** shows the results obtained where significant differences have been detected between those variables. Finally, **Table 4** presents the results from the analysis of the last established relational pair of categories (SP—rest of plays), where no significant differences have been found between them.

At a qualitative level, **Tables 5**, **6** present the results obtained through sequential-lag analysis of the Spanish and Italian leagues.

The goal-scoring pattern established in the Spanish league shows the player who occupies the winger position as the author of the goal, originating from offensive-action zones 22, 23, 42, and 43, generated by robbery (ROB), clearance (CLEAR), rebound (REB), or through a direct free kick (DFK), and ending in zones 43 and 52. The type of play that manifests itself is the counterattack (CA), in which three players intervene (P3) and two passes are used (PS2), finishing tactically by means of splits or overlaps (OVL) or other unstructured tactical alternatives (OTR2). The technical action by which the goal is scored consists of a single touch (TO1) executed with the inside of the foot (RIN, LIN), with an elevated trajectory (RS) and centered on goal (MIDD), occurring between minutes 11:00 and 15:59 of the first part (P13) with a favorable result (RV).

For its part, the Italian league presents a goal-scoring pattern in which the player who scores the goal occupies the winger and universal positions, having originated their offensive action from zones 22, 23, 42, and 43, generated by robbery (ROB) or pressure (PRS) and ending in zone 50. The type of play displayed is one in which the fly goalkeeper (FG) is used, in which four players (P4) intervene and three passes are used (PS3), finishing tactically with a pass to the center or the midfield (PM). The technical action by which the goal is scored consists of two touches (TO2) executed in the last instance, that is, the last contact with the ball, with the instep of the left foot (LIN) or with the toe, both right (RT) and left (LT), with a flat trajectory (LS) and directed to the left of the goal (LEFT), occurring both in the first period of the first (P10) and second half of the match (P20) with a tie result (RT).

TABLE 3 | Offensive actions that resulted in a goal according to the type of play in the Spanish and Italian leagues during the 2014–2015 season.

	Spanish league	Italian league	Total
PA	482 (27.7%)	168 (23.3%)	650
CA	465 (26.8%)	174 (24.2%)	639
CFG	126 (7.0%)	60 (7.8%)	186
PD	125 (7.0%)	47 (5.9%)	172
FG	110 (6.1%)	83 (11.1%)	193
SUP	19 (1.0%)	17 (1.7%)	39
INF	1 (0.1%)	0 (0.0%)	1
SP	424 (24.4%)	186 (26.0%)	610
Total	1,755 (100%)	735 (100%)	2,490

TABLE 4 | Results of the chi-squared test of the relationships between variables in both leagues.

	Value	df	Asymp. Sig. (bilateral)	*N* of valid cases
PA-CA	0.304	1	0.582	1,266
FG-CAFG	5.036	1	0.025*	357
SP- rest of plays	0.706	1	0.401	2,457

**Significant results.*

DISCUSSION

This study was proposed with two complementary objectives: firstly, to analyze and identify the types of plays corresponding to the offensive sequences resulting in goals in the two greatest European futsal leagues, the Spanish and Italian leagues, during the 2014-2015 season, and secondly, to identify and compare the behavioral patterns corresponding to their offensive actions that resulted in a goal in both leagues during that competition.

With reference to the first of these objectives, the results show that in the Spanish league, the highest number of goals (27.7%) was achieved through positional attack, which indicates that the action is carried out against a structured defense that is properly positioned, compared with 23.3% reached by the Italian league in this type of attack. Those results are consistent with those obtained by Álvarez et al. (2004) and Méndez et al. (2019), whose studies recognize that most of the goals scored occur through positional attacks.

With respect to the achievement of the goals through counterattack, as well as set piece actions, the results of both leagues are in close proximity to each other, resulting in 26.8 and 24.2% in the Spanish and Italian leagues, respectively, taking into account the first type, and 24.4% in the Spanish league and 26% in the Italian league with reference to the second, set pieces. Those results agree with the ones obtained by Álvarez et al. (2018) and Pascual et al. (2019), who determined that goals in futsal matches are produced through quick plays. In that respect, Álvarez et al. (2018) obtained differences between two seasons. In the 2012–2013 season, goals through positional attack and counterattack were very similar, with values higher than those of this study in both cases; in the 2013–2014 season, results were obtained that were very close to the ones presented in terms of the goals scored in counterattack, but much higher in those scored in positional attack, which shows that in the remaining actions, such as set pieces or fly goalkeeper, the goals scored were fewer than those obtained in our study.

In the Italian league, 11.1% of goals are scored using the goalkeeper-player, compared with 6.1% in the Spanish league. By account of the counterattack against the fly goalkeeper, referring

TABLE 5 | Significantly adjusted remainder that reflects sequential patterns of offensive actions leading to a goal in the Spanish futsal league.

	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
Position		WIN (18.5)					
Starting area		SA22 (3.18) SA23 (3.18) SA42 (5.57) SA43 (2.9)					
Ending area			EA11a (2.79) EA13a (2.57) EA43 (2.84) EA52 (4.21)				
Beginning			SP (2.42). CLEAR (4.26). REB (3.03). DFK (3.2)				
Type of move			CA (2.57)				
Players on the pitch				PL3 (3.8)			
Number of passes				PS2 (4.51)			
Ending of the game				OVL (5.43) ANOT3 (19.56)			
Number of touches					TO1 (5.22)		
Contact area					RIN (3.99) LIN (3.55)		
Penalty area						RS (3.63)	
Laterality of the penalty area						MIDD (12.76)	
Time of goal							P13 (2.24)
Prior result							RV (2.51)

Significant adjusted residuals of the lag sequential analysis for league.

TABLE 6 | Significantly adjusted remainder that reflects sequential patterns of offensive actions leading to a goal in the Italian futsal league.

	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 6
Position		WIN (3.52). UNI (23.49) INDEF (5.7)					
Starting area		SA22 (3.18). SA23 (3.18) SA42 (5.57). SA43 (2.9)					
Ending area			EA20 (2.73). EA50 (2.88)				
Beginning			SP (4.03). PRS (2.44)				
Kind of move			FG (3.74)				
Players on the pitch				PL4 (2.75)			
Number of passes				PS3 (4.33)			
Ending of the game				PM (2.66)			
Number of touches					TO2 (2.75)		
Contact area					LIN (3.06). RT (3.16) LT (2.82)		
Penalty area						LS (2.57)	
Laterality of the penalty area						LEFT (2.13)	
Time of goal							P10 (2.44) P20 (5.7)
Prior result							RD (2.06)

Significant adjusted residuals of the lag sequential analysis for league.

to the plays in which the ball is recovered when that situation is being defended and a goal is scored immediately thereafter, goals in counterattack would exceed those scored in positional attack in both leagues, 33.8% in the Spanish league and 32% in the Italian league, a figure that demonstrates the effectiveness of the plays in which the ball is recovered with a disorderly rival defense and the relevance reached by the transition phases (Jones et al., 2004) in the success of the offensive action.

As regards the second objective, two types of clearly differentiated patterns are identified that reveal the difference in how the two leagues score their goals, as has been set out in section "Results." However, when comparing the two goal-scoring patterns, we find several variants between them.

Firstly, by focusing on the player who scores the goal and his technical execution in doing so, we see how in the Spanish league the winger is the player that appears to be statistically significant, while in the Italian league we find that the goal is scored by the player who occupies the wing position but is predominantly marked as the universal player; in that instance, and unlike the Spanish league, the demarcation is exclusive to the Italian league, identifying the players who occupy that position as those who can play in any of the other three field positions (wing, pivot, and defender) (Álvarez et al., 2020).

Regarding the technical execution developed, the results show that the goal in the Spanish league is scored with a prior touch: the player controls the ball until the final hit, for which he makes use of the inside of his foot, seeking safety and precision. However, in the Italian league, the goal is scored with two prior touches, using the left instep or the toe; it seems clear that the player who finishes has time to prepare the shot, placing the ball well and striking with power, as shown by the surfaces used. Those results are diametrically opposed, those of the Spanish league matching those obtained by Pascual et al. (2019), which show that the surface most used to score a goal is the inside of the foot, and matching the results of the Italian league found by Lapresa et al. (2013), which show that the majority of goals are achieved via instep. This shows that there is no consensus as to the optimal hitting surface. On the other hand, considering the exact area where the ball enters the goal, the central space and half height are identified, which shows that when the player hits, the goalkeeper is out of position and cannot stop a ball that enters through the center of the goal. Those results are contrary to the ones obtained in the Italian league and by other studies, which all show that the bulk of goals come flat through the goal (Martín, 2009; Álvarez et al., 2018; Pascual et al., 2019).

Regarding the area in which those successful actions occur, the behavior patterns identified in both leagues coincide with the starting zones of play (SA22, SA23, SA42, and SA43), although their completion occurs in different areas, those being the border areas with the rival field (EA52) in the case of the Spanish league and in the areas belonging to the left lane, both in the player's field (EA20) and in their rival field (EA50), which are characteristic zones used by defensive teams to avoid completions by using the touchline to reduce the action space available to attacking players. Studies such as that of Lapresa et al. (2013); Álvarez et al. (2018), and Pascual et al. (2019) in respect of the end zone agree with the results obtained in the Spanish league. In addition to those area zones, this study, with reference to the Spanish league, shows the appearance of significant finishing zones in the player's own field (EA11a and EA13a), which relates to goals produced before attacks with the goalkeeper, who accounts for 6.1% of goals.

Based on the start of play, a pattern is established in the Spanish league where the action that reaches the goal begins after clearance or theft of the ball from the player, which means that the subsequent play is a counterattack in which three players participate, making two passes in the development of the action and a split as a technical-tactical element prior to the goal. In the Italian league, the start of play occurs after theft, as is the case most of the time in the Spanish league. However, the counterattack is not the standard type of play, but the favorable use of the fly goalkeeper, in which four players participate and there are three prior passes with a pass to the center as a technical-tactical action prior to the goal. Those results show a characteristic goal pattern at a qualitative level with a recovery of possession in central areas after theft of the ball, after which, in the Spanish league, there is a quick counterattack play to finish near the rival goal. Conversely, the Italian league prefers to adopt the approach of ensuring possession with the use of the fly goalkeeper through numerical superiority, not to look for a quick play that could cause a loss after recovery. Those results reveal two clear styles of play that predominate in each competition, being more elaborate in the Spanish league and more conservative in the Italian league.

Finally, with reference to the moment of the goal being scored and the previous result, the qualitative results show that, in the Spanish league, goals are scored from the 10th to the 15th min of the first half with a prior favorable result. That is a result contrary to the one obtained by Pascual et al. (2019), which shows that goals occur in the last 10 min of the game. In the Italian league, the results obtained do not establish differences between the two parties and they do not specify the result prior to the goal.

CONCLUSION

Throughout this study, we have given a response to the established objectives set out in the research. Firstly, the typology of the moves that result in a goal of the two best European futsal leagues have been analyzed and identified, the counterattack being the type that stands out for its reach in the Spanish league, while set pieces appear to be preferred in the Italian league.

As for the second of the objectives set out in this research, two behavioral patterns have been identified for goal-scoring that strengthen the previous conclusion, but in this case from a qualitative perspective, where they show the manner in which goals are scored.

In the case of the Spanish league, the winger's territory is clearly defined by a counterattack action that takes place in the middle zones of the field and in which two players intervene, scoring the goal through splits and technical executions, which is simple (by means of a single touch) yet complex (due to the direction and precision of where the ball enters the center top region of the goal).

As for the Italian league, a pattern of behavior is revealed with the following structure: the player who occupies the universal position scores a goal, initiating the offensive action in central areas of the own field and the rival field after theft, and finishing it from the left lane both from the own field and the rival field, the usual type of play being the favorable use of the fly goalkeeper, in which four players participate and there are three prior passes, with a pass to the center as a technical-tactical action prior to the goal. The execution of the shot to goal is composed of two touches using the left instep or the toe, and the ball enters the goal flat.

In light of the results obtained, it can be inferred that scoring a goal in the Spanish league is most effective in developing offensive transitions, which lead to a greater complexity and speed of the game; this, in turn, demands a higher standard of players and teams, both technically and tactically. Conversely, in the Italian league, set-piece actions are the first option to achieve the goal, which highlights the relevance of that type of action in a match, as well as the differences in the game between the two best European leagues of the last decade.

PRACTICAL APPLICATIONS

The results obtained will enable technicians to gain a better understanding of how goals are scored and will allow them to set more specific training tasks, in both attack and defense. Thanks to established patterns, tasks can be conditioned through the type of defense or attack to be used, determining, in a pre-established and priority-based manner, how, when, and where to end the move.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

All authors have participated in the preparation and layout of the manuscript.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 05 May 2021
doi: 10.3389/fpsyg.2021.625354

Characterization of Reproductive and Morphological Variables in Female Elite Futsal Players

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Edited by:
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Reviewed by:
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Pedro Alexandre Duarte-Mendes, Instituto Politécnico de Castelo Branco, Portugal

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: 02 November 2020
Accepted: 06 April 2021
Published: 05 May 2021

Citation:
Queiroga MR, da Silva DF, Ferreira SA, Weber VMR, Fernandes DZ, Cavazzotto TG, Portela BS, Tartaruga MP, Nascimento MA and Vieira ER (2021) Characterization of Reproductive and Morphological Variables in Female Elite Futsal Players. Front. Psychol. 12:625354. doi: 10.3389/fpsyg.2021.625354

We aimed to characterize the age of onset of training, age at menarche, menstrual periodicity, and performance perception during the menstrual cycle and examined the impact of these reproductive variables on body composition, morphology, and body weight satisfaction in Brazilian elite futsal players. The study consisted of 115 female Brazilian elite futsal players from the top national teams. Data were collected during the twentieth Women's Brazil Futsal Cup. Players were interviewed and self-reported their age of onset of training, age at menarche, menstrual periodicity, and the menstrual period, where they performed best. We also asked for what they considered to be their ideal body weight as well as information related to their training (i.e., volume and frequency). Subsequently, anthropometric measurements (i.e., body mass, height, circumferences, diameters, and skinfold thickness) were performed to estimate the body composition and determine morphological characteristics (e.g., somatotype). Fifty-nine (53.2%) players were postmenarche-trained and 52 (46.8%) were premenarche-trained. Eighteen (16.2%), 65 (58.6%), and 28 (25.2%) were classified as early, normal, and late menarche, respectively. Only 11 (9.6%) and 1 (0.9%) had irregular menstrual cycles and were amenorrheic, respectively. Seventy-three (69.5%), 23 (21.9%), and 9 (8.6%) reported that their game performance was the best at the follicular phase, menses, and luteal phase of the menstrual cycle, respectively. No associations between the four reproductive-related variables were found. Postmenarche-trained players had significant lower age at menarche and higher percentage body fat. The somatotype profile registered lower ectomorphy rate for the postmenarche-trained participants after controlling for covariates. Early menarche group presented higher sum of six skinfold thickness and endomorphy rate compared to normal and late menarche groups. No differences were found when menstrual periodicity groups and best performance groups were compared, except for higher femur width in the regular menstrual cycle group compared to the irregular one. The association between body weight satisfaction and the four reproductive-related variables were not observed.

Premenarche-trained Brazilian elite futsal players had the menarche later than the postmenarche-trained athletes. Most of the participants had menarche age classified as "normal," presented "regular" menstrual cycles and perceived to perform better during the follicular phase of the menstrual cycle.

Keywords: female athletes, sports medicine, early puberty, five-a-side football, reproductive health, menstrual cycle, soccer, women

INTRODUCTION

Exercise training can directly impact female reproductive health. Over 40 years of research have shown that female athletes are susceptible to oligomenorrhea and amenorrhea when compared to non-athletic populations (Dale et al., 1979; Frisch, 1980; Calthorpe et al., 2019). Moreover, a recent systematic review with meta-analysis revealed that age at menarche is 1.13 (95% CI: 0.80–1.47) years later in trained vs. non-trained girls (Calthorpe et al., 2019). It is worth mentioning that none of the included studies had team sport female athletes involved (Calthorpe et al., 2019).

Irregular menstrual cycle may pose as a risk for female reproductive health (Ackerman and Misra, 2018). However, later menarche can be protective against some chronic diseases when compared to having an early menarche. Epidemiological research has suggested that early age at menarche is associated with increased risk of cancer (Werneck et al., 2018a), higher blood pressure (Werneck et al., 2018b), gestational diabetes mellitus (Schoenaker and Mishra, 2017), and all-cause mortality (Tamakoshi et al., 2011). With regards to exercise performance, there is evidence that later menarche is associated with superior athletic performance (Stager et al., 1984), although the field of alterations related to the menstrual cycle and athletic performance has considerable controversial findings (e.g., no impact or some impact being previously reported; McNulty et al., 2020).

One factor that seems to influence later menarche is the onset of exercise training. Menstrual disturbances have been reported to be relatively more common in athletes who began training before the menarche. The premenarche-trained athletes reported a higher incidence of menstrual cycle irregularities than the athletes who began training after the menarche (Toriola, 1988). Frisch (1980) found that each year of training before menarche has accounted for 5 months of delay in the menarche in college athletes. Furthermore, premenarche-trained athletes presented high rates of irregular menstrual cycle (61%) and amenorrhea (22%; Frisch, 1980).

Menstrual dysfunctions can be caused by low energy availability or energy deficiency (Mountjoy et al., 2014; Ackerman and Misra, 2018). Low energy availability is linked with a disbalance between energy intake and energy expenditure, which can ultimately lead to lower body fat content (Loucks, 2004). Thus, low body fat, as a result of a disbalanced energy storage, can lead to changes in the menstrual cycle (Mountjoy et al., 2014) and may be a common characteristic of women with menstrual dysfunctions (Carlberg et al., 1983). Psychological aspects, such as eating disorder behaviors, can also influence female reproductive health by altering body weight and body fat content. Rates of eating disorders and body image alterations are 13.3 and 24.4% in female team sport athletes including futsal players (Kravchychyn et al., 2013).

The association between physical training and reproductive health issues, particularly in elite athletes, is a big concern of the sport and exercise scientific community. With regards to elite futsal players, to the best of our knowledge, the rates of menstrual dysfunctions have yet to be described. In fact, there is a lack of reproductive health-related information available in the team sport literature (Findlay et al., 2020). One potential explanation for a reduced focus on team sports is that research tends to focus on sports, which encourage leanness (Bruinvels et al., 2017), assuming that lower body fat and an ectomorphic somatotype would be potentially linked with higher rates of menstrual dysfunction (Mountjoy et al., 2014). To further explore this assumption, the present study aimed to characterize the age of onset of training, age at menarche, menstrual periodicity, and performance perception during the menstrual cycle and examined the impact of these reproductive variables on body composition, morphology, and body weight satisfaction in Brazilian elite futsal players. We hypothesized that premenarche-trained, late menarche, and athletes with irregular menstrual cycles would have greater rates of menstrual dysfunction, lower body fat, higher ectomorphy morphological profile, and greater dissatisfaction with body weight. We also hypothesized the study outcomes would not differ between menstrual periods when participants perceive to perform best.

MATERIALS AND METHODS

Study Design and Subjects

Study design is cross-sectional. One-hundred and fifteen female Brazilian elite futsal players from the top national teams were recruited for the present study. The recruitment process was conducted through the Brazilian Confederation of Futsal with the support of the coaches of the teams. Eligibility criteria were checked and validated by the leading research investigator. The inclusion criterion was being registered for the twentieth Women's Brazil Futsal Cup. No exclusion criteria were applied. The sample comprehended the population of female Brazilian elite futsal players. Since 1992, this national competition is a yearly event organized by the Brazilian Futsal Confederation[1]

[1]http://www.cbfs.com.br

between the 10 top teams in the country. One represents the host city and the other nine are champions from other Brazilian states. The study was approved by the Local Ethics Board (Process n. 039/2011) and complies with the Resolution of the National Health Council of the Brazilian Ministry of Health and the Declaration of Helsinki on human research. All players were fully informed about the purpose of the study and signed the consent form before any procedure took place.

Measures

All measurements were conducted by the leading research investigator. The twentieth Women's Brazil Futsal Cup format allowed each team to take 1 day off. In this way, data collection was performed in a room, in the same place, where the games were played and coincided with this day off of the teams, which allowed a minimum interval of 15 h between the last game and the evaluation. Thus, all the assessments were performed in a single day. Before performing the anthropometrical measurements, participants were interviewed following a structure interview with close-ended question and self-reported four reproductive-related variables:

1. Age of onset of training (years). This was measured based on a close-ended question (*what was your age, in years, of onset of training?*). Depending on the age at menarche, athletes were classified as premenarche-trained and postmenarche-trained (Frisch, 1980);
2. Age at menarche (years). This was measured based on a close-ended question (*what was your age, in years, at menarche?*). This variable was classified as early menarche (<12 years), normal menarche (12–14 years), and late menarche (>14 years; Day et al., 2015);
3. Menstrual periodicity. This was measured based on a close-ended question (for the most part of your reproductive years, what is your menstrual cycle periodicity? Options: 10–13 cycles/year; 3–9 cycles/year; and 0–2 cycles/year). Regular menstrual cycles were considered between 10 and 13 cycles/year, irregular menstrual cycles between 3 and 9 cycles/year and amenorrheic 0–2 cycles/year (Frisch, 1980);
4. Menstrual period when they performance best. This variable was obtained based on a close-ended question (*based on your perception, which menstrual period do you perform the best? Options: Menses; Luteal Phase; and Follicular Phase*). Based on their own perception, they answered one of the three options.

Besides that, they were also asked:

5. Ideal body weight (kg) and body weight satisfaction (classified as "Satisfied," "No, increase," and "No, decrease"). Ideal body weight was asked as a close-ended question (*what is your ideal body weight in kg?*). Body weight satisfaction was also a close-ended question (*are you satisfied with your body weight? Options: Yes; No, increase; and No, decrease*).
6. Information related to their training (i.e., volume and frequency). These data were also obtained with a close-ended question (*what is your training volume?* and *what is your training frequency?*). They were asked to report training volume in hours/week, minutes/week, or hours:minutes/week. We converted all answers in minutes/week before moving to data analysis. Training frequency was reported in times/week.

Anthropometric variables were checked in duplicate in the right hemisphere of the body. If the difference was greater than 0.2 mm for skinfolds or 0.5 cm for other variables, a third measurement was performed. The final result used for data analysis was the average of two or three measurements. All anthropometric measurements were performed with athletes wearing no shoes and only light clothing, in accordance with standardized procedures (Marfell-Jones et al., 2006). They have been already described in more details elsewhere (Queiroga et al., 2019). Measurements were taken in a private room at approximately the same time of the day for all participants during a period of 5 days. Body mass was assessed by a 100-g precision anthropometric scale (Welmy™ São Paulo, Brazil) and height was measured by a 0.1-cm precision wall-mounted stadiometer. Body mass index (BMI) was calculated as body mass (kg)/height squared (m^2). Biceps girth (mid-upper-arm) and calf girth (cm) were measured using a non-elastic tape to the nearest 0.1 cm (Mabis™ Curitiba, Brazil). The Biceps girth (cm) was obtained with the arm in a tensed position, while calf girth (cm) was measured in a seated position with legs on the ground. Biepicondylar humerus and femur width were measured to the nearest 0.1 cm with a metal caliper (Somet™ Curitiba, Brazil).

Skinfold thickness (SKFT) was measured at six sites (triceps, subscapular, supraspinal, suprailiac, midthigh, and medial calf) to the nearest 0.1 mm with a Cescorf caliper (Cescorf™ Porto Alegre, Brazil).

The sum of three skinfold thicknesses (3SKFT; triceps + suprailiac + midthigh) determined body density (Jackson et al., 1980). Body fat percentage (%BF) was subsequently estimated (Siri, 1961). Fat mass (FM) and lean body mass (LBM) were calculated in kg: FM = (%BF/100) × body mass; LBM = body mass − FM. The three somatotype components (i.e., endomorphy, mesomorphy, and ectomorphy) were determined according to the Heath and Carter Anthropometric Somatotyping Method (Carter and Health, 1990). All variables were measured in duplicate in the right side of the body. A third measure was taken if a difference greater than 0.2 mm for skinfold thickness or 0.5 cm difference for all the other variables was recorded. The final score used in the data analysis was the mean of the two scores or the median of three scores. The technical error of measurement of the leading research investigator who conducted all the measurements was between 2.9 and 3.5% for SKFT and between 0.1 and 1.8% for the other anthropometric measurements. The intra-class correlation for the measurements varied between 0.98 and 0.99 for SKFT and between 0.95 and 0.99 for the other measurements.

Statistical Analysis

Data were descriptively analyzed using mean ± standard deviation (SD), frequencies, and percentages. The associations between the four reproductive-related variables and body weight satisfaction were tested with Chi-square test. When more than 20% of cells had expected count less than 5, the Likelihood Ratio correction was applied. Cramer's V was calculated as an effect size measurement of the associations.

Body composition and morphological variables were compared according to the four reproductive-related variables with one-way ANCOVA adjusting for the time of experience in the sport, training volume, and frequency. Effect sizes for comparisons were computed using partial eta squared (η^2). Bonferroni correction was applied when significant differences were captured in the adjusted one-way ANCOVA. Significance was set at $p < 0.05$ for all analyses.

RESULTS

One-hundred and fifteen female Brazilian elite futsal players (age: 22.0 ± 3.9 years; body weight: 58.6 ± 7.6 kg; height: 161.8 ± 6.5 cm; BMI: 22.3 ± 2.2 kg/m^2; and body fat: 22.2 ± 5.0%) were evaluated; however, four did not report the age at menarche. The average of their age at menarche was 13.1 ± 1.8 years, the time of experience was 9.0 ± 4.3 years, the training volume was 171.9 ± 77.4 min/week, and the training frequency was 5.2 ± 1.8 times/week.

Fifty-nine (53.2%) players were postmenarche-trained and 52 (46.8%) were premenarche-trained. Eighteen (16.2%), 65 (58.6%), and 28 (25.2%) were classified as early, normal, and late menarche, respectively. Only 11 (9.6%) and 1 (0.9%) had irregular menstrual cycles and were amenorrheic, respectively. Seventy-three (69.5%), 23 (21.9%), and 9 (8.6%) reported that their game performance was the best at the follicular phase, menses, and luteal phase of the menstrual cycle, respectively. No associations between the four reproductive-related variables were found (**Table 1**).

After adjusting for the time of experience in the sport, training volume, and frequency, postmenarche-trained players had significant higher age and lower age at menarche than premenarche-trained players. They also presented higher body fat (kg). The somatotype profile registered lower ectomorphy rate for the postmenarche-trained participants (**Table 2**).

When women with early, normal, and late menarche were compared, applying the same adjustments, we observed higher of sum of the six SKFT and endomorphy rate for the early menarche group compared to both normal and late menarche groups (**Table 3**). No significant results were evidenced in the comparison between women with regular vs. irregular menstrual cycle, except for higher femur width in the regular menstrual cycle group (**Table 4**). Women who perceived their performance to be the best at menses compared to follicular phase or luteal phase also did not differ for any anthropometric variable (**Table 5**).

After adjusting for time of experience in the sport, training volume, and frequency, the perception of ideal body weight and difference between ideal and real body weight were not different between categories of onset of training, age of menarche, menstrual periodicity, and menstrual period when athletes reported to perform best (**Table 6**).

The association between body weight satisfaction and the four reproductive-related variables is represented in **Figures 1A–D**. No significant results were found.

DISCUSSION

The purpose of this study was to characterize the age of onset of training, age at menarche, menstrual periodicity, and performance perception during the menstrual cycle and examined the impact of these reproductive variables on body composition, morphology, and body weight satisfaction in Brazilian elite futsal players.

The main findings of this research were that the number of female futsal players who engaged on the sport before menarche is balanced with the number of women who embarked on futsal training after the menarche. Those who engaged before the menarche had the menarche significantly later than those who started training after the menarche. Premenarche-trained players had lower body fat (kg) and greater ectomorphy profile after controlling for time of experience in the sport, training volume, and frequency. In addition, our descriptive analysis showed that most of the participants of the present study had their menarche age classified as "normal," presented a "regular" menstrual cycle and perceived to perform better during the follicular phase of the menstrual cycle. Nonetheless, these factors did not associate with each other.

TABLE 1 | Associations between the four reproductive-related variables.

Onset of training	Age of menarche			*p*	Cramer's V
	Early	Normal	Late		
Premenarche-trained	6	29	17	0.164	0.180
Postmenarche-trained	12	36	11		
Menstrual periodicity					
Normal	16	58	25		
Irregular	2	6	3	0.887*	0.059
Amenorrheic	0	1	0		
Best performance					
Menses	4	13	4		
Follicular phase	12	42	19	0.869*	0.076
Luteal phase	2	5	1		
	Menstrual periodicity				
Onset of training	**Normal**	**Irregular**	**Amenor**		
Premenarche-trained	48	3	1	0.183*	0.163
Postmenarche-trained	51	8	0		
Best performance					
Menses	20	3	0		
Follicular phase	66	6	1	0.681*	0.104
Luteal phase	7	2	0		
	Best performance				
Onset of training	**Menses**	**Follicular**	**Luteal**		
Premenarche-trained	10	31	6	0.204*	0.174
Postmenarche-trained	11	42	2		

*Values of p represent Pearson Chi-Square test. *Values of p represent Likelihood Ratio correction. Amenor. = Amenorrheic.*

Intense training has been found to delay the onset of puberty in females by altering normal hormonal development (Theintz, 1994; Matina and Rogol, 2011; Malina et al., 2013).

TABLE 2 | Age, training, and anthropometric characteristics of premenarche-trained and postmenarche-trained female Brazilian elite futsal players.

	Onset of training		*p*	η^2
	Premenarche-trained (*n* = 52)	Postmenarche-trained (*n* = 59)		
Age (years)	20.9 ± 3.6	22.8 ± 4.0	**<0.001**	0.464
Age at menarche (years)	13.5 ± 1.6	12.7 ± 1.9	**0.024**	0.047
Training volume (min/week)	169 ± 64	174 ± 88	0.155	0.019
Training frequency (times/week)	5.6 ± 2.0	4.9 ± 1.6	0.231	0.013
Body weight (kg)	58.0 ± 5.9	59.5 ± 8.7	0.131	0.021
Height (cm)	163 ± 6	162 ± 7	0.825	<0.001
BMI (kg/m^2)	21.9 ± 2.1	22.7 ± 2.2	0.057	0.034
6SKFT (mm)	94 ± 20	103 ± 27	0.054	0.035
Body fat (%)	21.0 ± 4.4	23.2 ± 5.4	0.054	0.035
Body fat (kg)	12.3 ± 3.5	14.1 ± 5.2	**0.040**	0.039
Lean mass (kg)	45.7 ± 3.9	45.4 ± 4.9	0.637	0.002
Humerus width (cm)	6.1 ± 0.3	6.1 ± 0.3	0.835	<0.001
Femur width (cm)	8.8 ± 0.4	8.9 ± 0.5	0.846	<0.001
Biceps girth (tensed) (cm)	25.8 ± 1.8	25.9 ± 1.8	0.406	0.007
Calf girth (cm)	33.8 ± 2.0	34.3 ± 2.0	0.228	0.014
Endomorphy	4.2 ± 1.0	4.7 ± 1.2	0.060	0.033
Mesomorphy	4.0 ± 1.0	4.3 ± 0.8	0.293	0.010
Ectomorphy	2.3 ± 1.1	1.9 ± 0.9	**0.032**	0.042

Data are presented as mean ± standard deviation. Bold represents statistically significant differences. Comparisons were performed with one-way ANCOVA adjusting for time of experience in the sport, training volume, and frequency. Min, minutes; BMI, body mass index; 6SKFT, sum of six skinfold thickness.

A systematic review with meta-analysis has shown that age at menarche is 1.13 (95% CI: 0.80–1.47) years later in trained vs. non-trained girls (Calthorpe et al., 2019). The age difference between premenarche-trained vs. postmenarche-trained in the present study is about 1.9 years.

Besides later menarche, female athletes are known to be more susceptible to oligomenorrhea and amenorrhea when compared to non-athletic populations (Dale et al., 1979; Frisch, 1980; Calthorpe et al., 2019). A relevant biological causal factor for the menstrual dysfunctions is low energy availability (Ackerman and Misra, 2018). Although we did not measure energy intake or energy balance, premenarche-trained futsal players had lower body fat (kg) than their postmenarche-trained counterparts. The ranges of body fat in our study are within the range from other studies with female futsal players of different performance levels (i.e., elite, sub-elite, and amateur; Barbero-Alvarez et al., 2015; Ramos-Campo et al., 2016; Beato et al., 2018; Palucci Vieira et al., 2020).

Also, our study demonstrated that women with early menarche presented higher sum of six SKFT and endomorphy rate compared to women whose menarche was classified as normal and late. The relationship between early age at menarche and higher adiposity is not completely elucidated; however, three factors have been suggested: (i) early menarche girls have longer exposure to a positive energy balance and (ii) endocrine factors, such as high levels of estrogen and GnRH, may accelerate pubertal development and increase subcutaneous body fat accumulation (Garn et al., 1986; Cole, 2003).

On the other hand, no differences in body fat were found in the comparison between groups related to menstrual periodicity (i.e., regular vs. irregular) and menstrual period when performance is perceived to be the best (i.e., menses, follicular, or luteal phases). Other anthropometric, body composition, and morphology variables

TABLE 3 | Age, training, and anthropometric characteristics of female Brazilian elite futsal players classified as early, normal, and late menarche.

	Age of menarche			*p*	η^2
	Early (*n* = 18)	Normal (*n* = 65)	Late (*n* = 28)		
Age (years)	21.6 ± 4.0	21.9 ± 4.1	22.1 ± 3.4	0.853	0.003
Age at menarche (years)	10.3 ± 1.2	12.9 ± 0.7†	15.4 ± 0.7†,‡	**<0.001**	0.795
Training volume (min/week)	188 ± 103	164 ± 71	179 ± 74	0.246	0.026
Training frequency (times/week)	4.7 ± 1.8	5.3 ± 1.6	5.3 ± 2.1	0.365	0.019
Body weight (kg)	59.1 ± 9.9	58.6 ± 7.3	59.3 ± 6.6	0.811	0.004
Height (cm)	163 ± 7	162 ± 6	162 ± 7	0.789	0.004
BMI (kg/m^2)	22.2 ± 2.9	22.3 ± 2.0	22.5 ± 2.1	0.873	0.003
6SKFT (mm)	113 ± 32	97 ± 23†	94 ± 20†	**0.013**	0.080
Body fat (%)	24.7 ± 6.1	21.7 ± 4.8	21.6 ± 4.5	0.050	0.056
Body fat (kg)	15.0 ± 5.8	12.9 ± 4.5	13.0 ± 3.8	0.160	0.034
Lean mass (kg)	44.1 ± 5.6	45.6 ± 4.2	46.3 ± 4.1	0.315	0.022
Humerus width (cm)	6.1 ± 0.3	6.0 ± 0.3	6.1 ± 0.3	0.285	0.024
Femur width (cm)	8.9 ± 0.6	8.8 ± 0.5	8.8 ± 0.4	0.705	0.007
Biceps girth (tensed) (cm)	26.0 ± 2.4	25.7 ± 1.6	26.3 ± 1.8	0.252	0.026
Calf girth (cm)	33.6 ± 2.5	34.1 ± 1.9	34.1 ± 1.7	0.632	0.009
Endomorphy	5.1 ± 1.5	4.4 ± 1.0†	4.3 ± 1.0†	**0.030**	0.065
Mesomorphy	4.1 ± 1.1	4.1 ± 0.8	4.2 ± 1.0	0.815	0.004
Ectomorphy	2.2 ± 1.2	2.0 ± 0.9	2.0 ± 1.0	0.821	0.004

Data are presented as mean ± standard deviation. Bold represents statistically significant differences. Comparisons were performed with one-way ANCOVA adjusting for time of experience in the sport, training volume, and frequency. †Statistically different from Early group. Min, minutes; BMI, body mass index; 6SKFT, sum of six skinfold thickness. ‡Statistically different from Normal group.

TABLE 4 | Age, training, and anthropometric characteristics of female Brazilian elite futsal players classified as regular and irregular menstrual cycle.

	Menstrual periodicity			p	η^2
	Regular (n = 103)	Irregular (n = 11)	Amenorrheic (n = 1)		
Age (years)	22.0 ± 3.8	22.0 ± 4.2	---	0.166	0.032
Age at menarche (years)	13.2 ± 1.7	12.5 ± 2.5	---	0.606	0.009
Training volume (min/week)	176 ± 82	164 ± 71	---	0.748	0.005
Training frequency (times/week)	5.2 ± 1.8	5.1 ± 1.6	---	0.974	<0.001
Body weight (kg)	59.0 ± 7.8	55.5 ± 5.1	---	0.302	0.022
Height (cm)	162 ± 7	158 ± 5	---	0.199	0.029
BMI (kg/m^2)	22.4 ± 2.2	22.2 ± 2.0	---	0.713	0.006
6SKFT (mm)	99 ± 25	98 ± 28	---	0.636	0.008
Body fat (%)	22.3 ± 5.2	21.5 ± 5.0	---	0.636	0.008
Body fat (kg)	13.4 ± 4.7	12.1 ± 3.7	---	0.468	0.014
Lean mass (kg)	45.6 ± 4.6	43.4 ± 2.9	---	0.373	0.018
Humerus width (cm)	6.1 ± 0.3	6.0 ± 0.2	---	0.877	0.002
Femur width (cm)	8.9 ± 0.5	8.5 ± 0.4	---	**0.037**	0.059
Biceps girth (tensed) (cm)	25.9 ± 1.9	25.4 ± 1.4	---	0.779	0.005
Calf girth (cm)	34.1 ± 2.0	33.3 ± 1.9	---	0.394	0.017
Endomorphy	4.5 ± 1.1	4.6 ± 1.3	---	0.840	0.003
Mesomorphy	4.1 ± 0.9	4.2 ± 1.0	---	0.999	<0.001
Ectomorphy	2.1 ± 1.0	1.9 ± 1.0	---	0.756	0.005

Data are presented as mean ± standard deviation. Bold represents statistically significant differences. Comparisons were performed with one-way ANCOVA adjusting for time of experience in the sport, training volume, and frequency. Min, minutes; BMI, body mass index; 6SKFT, sum of six skinfold thickness.

TABLE 5 | Age, training, and anthropometric characteristics of female Brazilian elite futsal players according to the menstrual phase that they perceive to perform best.

	Best performance			p	η^2
	Menses (n = 23)	Follicular (n = 73)	Luteal (n = 9)		
Age (years)	23.3 ± 3.3	21.5 ± 4.0	21.0 ± 4.6	0.519	0.013
Age at menarche (years)	12.7 ± 2.0	13.2 ± 1.8	12.3 ± 2.1	0.234	0.030
Training volume (min/week)	175 ± 82	173 ± 81	193 ± 84	0.768	0.005
Training frequency (times/week)	4.8 ± 2.4	5.2 ± 1.7	5.3 ± 0.5	0.188	0.033
Body weight (kg)	58.3 ± 7.9	58.7 ± 7.6	61.6 ± 7.8	0.464	0.015
Height (cm)	163 ± 7	162 ± 6	163 ± 6	0.915	0.002
BMI (kg/m^2)	22.0 ± 2.1	22.4 ± 2.2	23.3 ± 2.4	0.315	0.023
6SKFT (mm)	100 ± 24	101 ± 26	96 ± 29	0.923	0.002
Body fat (%)	22.2 ± 4.8	22.8 ± 5.2	21.6 ± 5.7	0.898	0.002
Body fat (kg)	13.1 ± 4.1	13.6 ± 4.8	13.6 ± 5.1	0.955	0.001
Lean mass (kg)	45.1 ± 5.3	45.1 ± 4.3	48.0 ± 3.9	0.176	0.034
Humerus width (cm)	6.0 ± 0.3	6.1 ± 0.3	6.1 ± 0.3	0.753	0.006
Femur width (cm)	8.8 ± 0.4	8.9 ± 0.5	8.9 ± 0.6	0.432	0.017
Biceps girth (tensed) (cm)	25.6 ± 1.5	25.8 ± 1.8	26.7 ± 2.4	0.251	0.028
Calf girth (cm)	33.3 ± 1.9	34.1 ± 1.9	34.8 ± 2.4	0.122	0.042
Endomorphy	4.6 ± 1.0	4.6 ± 1.2	4.5 ± 1.5	0.902	0.002
Mesomorphy	3.8 ± 0.8	4.2 ± 0.9	4.4 ± 1.1	0.169	0.035
Ectomorphy	2.2 ± 1.0	2.0 ± 1.0	1.7 ± 1.0	0.469	0.015

Data are presented as mean ± standard deviation. Comparisons were performed with one-way ANCOVA adjusting for time of experience in the sport, training volume, and frequency. Min, minutes; BMI, body mass index; 6SKFT, sum of six skinfold thickness.

did not differ between the four reproductive-related variables in Brazilian elite futsal players, except for femur width that was higher in the group with regular menstrual cycles compared to the irregular menstrual cycle group. Despite the significant results, this difference was only about 0.4 cm, which does not seem to be clinically important. Thus, our findings suggest that changes in reproductive variables are not related to relevant physical changes in this population. This agrees with Merzenich et al. (1993) who showed that exposure to exercise training may affect age at menarche through pathways that may go beyond adiposity.

Moreover, the percentage of women with normal age range menarche and regular menstrual cycle was much higher (58.6% for normal age range at menarche and 89.5% for regular menstrual cycle) in the present study compared to others. Frisch (1980) found that 61 and 22% of the premenarche-trained swimmers and runners had irregular menstrual cycle and were amenorrheic, and 60% of the postmenarche-trained swimmers and runners had regular menstrual cycles. In our study, 92.3% of the premenarche-trained and 86.4% of the postmenarche-trained had regular menstrual cycle. The reason for high rates of regular

TABLE 6 | Perception of ideal body weight and difference between ideal and real body weight according to categories of onset of training, age of menarche, menstrual periodicity, and menstrual period when athletes reported to perform best.

Onset of training	Ideal BW (kg)	Diff ideal-real BW
Premenarche-trained (*n* = 50)	57.1 ± 4.7	−1.1 ± 3.7
Postmenarche-trained (*n* = 57)	57.7 ± 6.7	−2.0 ± 3.6
p	0.172	0.202
*η*2	0.018	0.016
Age of menarche		
Early (*n* = 17)	57.1 ± 6.7	−2.3 ± 4.9
Normal (*n* = 62)	57.4 ± 5.8	−1.4 ± 3.5
Late (*n* = 28)	57.7 ± 5.7	−1.5 ± 3.2
p	0.950	0.447
*η*2	0.001	0.016
Menstrual periodicity		
Regular (*n* = 99)	57.6 ± 6.1	−1.6 ± 3.7
Irregular (*n* = 11)	54.6 ± 2.6	−0.9 ± 3.6
Amenorrheic (*n* = 1)	---	---
p	0.342	0.426
*η*2	0.020	0.016
Best performance		
Menses (*n* = 21)	57.6 ± 6.6	−1.1 ± 3.5
Follicular phase (*n* = 71)	57.0 ± 5.7	−1.9 ± 3.8
Luteal phase (*n* = 9)	60.0 ± 5.5	−1.6 ± 3.5
p	0.383	0.888
*η*2	0.020	0.003

Data are presented as mean ± standard deviation. Comparisons were performed with one-way ANCOVA adjusting for time of experience in the sport, training volume, and frequency. BW, body weight.

menstrual cycle can be related to the training volume of Brazilian female futsal players. Both groups had low training volume. Delayed age at the first menarche has been reported in young girls involved in athletic training for at least 15 h/week (Thomis et al., 2005). In the present study, the post-menarche-trained and pre-menarche-trained reported a much lower training volume, which was 174 ± 88 min and 164 ± 64 min (≈3 h/week – 2–6 h/week), respectively. Thus, the low training volume of the present sample is probably a strong contributor of the low rates of menstrual dysfunctions in Brazilian elite futsal players.

Another factor previously associated with menstrual dysfunctions is eating disorder behaviors (Mountjoy et al., 2014; Ackerman and Misra, 2018). A previous study with female athletes of team sports, including futsal, noticed that 13.3% of the sample had eating disorders (Kravchychyn et al., 2013). The authors also found that 24.4% of the sample presented body image distortion, and the team sport athletes of higher BMI and percentage body fat had greater risk for body image distortion (Kravchychyn et al., 2013). In the present study, we did not find associations between body weight satisfaction and the four reproductive-related variables. However, our data demonstrate large rates of body weight dissatisfaction, with most of the participants willing to decrease their body weight.

The majority of our sample perceived their performance to be the best in the follicular phase of the menstrual cycle and only a few participants said that the luteal phase was their best period for performing. This can be supported by physical and physiological data, indicating a reduction in maximal endurance

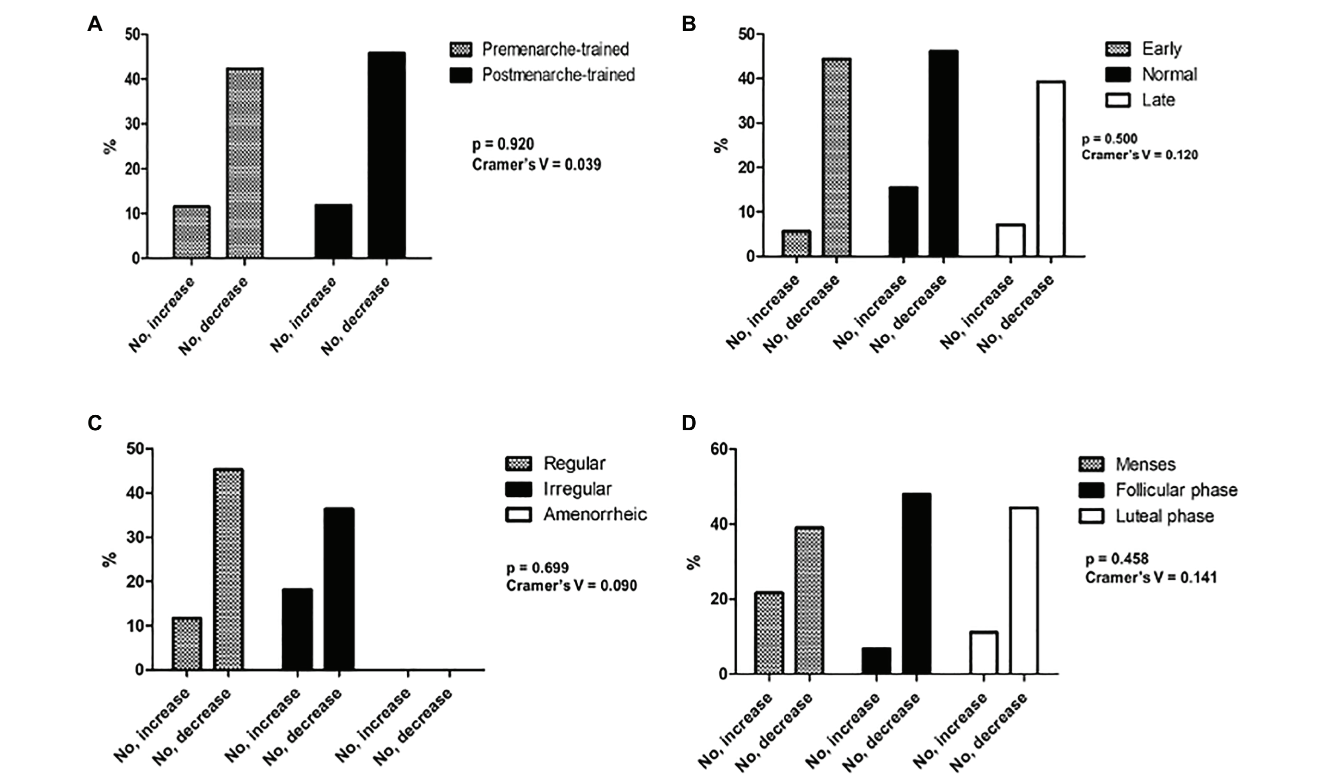

FIGURE 1 | Association between body weight satisfaction and the four reproductive-related variables **(A–D)**.

performance during the luteal phase of the menstrual cycle in nine sub elite female soccer players (Julian et al., 2017). However, these authors did not find the same effect or jumping and sprint performance (Julian et al., 2017). Evidence suggests that maximum endurance performance during the menstrual cycle is at its lowest during menstruation and/or the luteal phase (Janse de Jonge, 2003). With regards to strength-related variables, a systematic review that investigated changes in strength-related variables during different phases of the menstrual cycle in eumenorrheic women recommends caution in the interpretation of results due to the methodological shortcomings identified by the quality assessment (Blagrove et al., 2020). Strength-related measures appear to be minimally altered ($g \leq 0.35$) by the fluctuations in ovarian sex hormones that occur during the menstrual cycle (Blagrove et al., 2020). Given the aerobic predominance of futsal, it is expected that women would perceive the follicular phase as the best to perform. The physiological mechanism behind the explanation for a greater performance perception in the follicular phase can be related to the link between the follicular phase with reduced sympathetic autonomic activity and lower emotional stress (Tada et al., 2017). Recent research has suggested that greater parasympathetic activity is associated with increased performance in futsal players (Nakamura et al., 2020). Nonetheless, women who perceived their performance to be the best during the follicular phase compared to the other menstrual phases did not differ in the onset of training, anthropometric characteristics, and the perception of ideal body weight.

Our study has four important strengths. First, we characterized reproductive-related variables and menstrual dysfunctions in elite futsal players. In addition, we assessed women who participate in the largest futsal competition in Brazil, which allow us to have a representative sample of female Brazilian elite futsal players. The third strength is the strong and standard methodological procedures to determine anthropometric variables and, subsequently, body composition and morphological variables. The last point is the inclusion of relevant physical aspects (i.e., anthropometric variables) and a perceptual aspect (i.e., body weight satisfaction) that could be linked with menstrual dysfunctions. We also have limitations. Although we were able to access a large cohort of Brazilian elite futsal players, the lack of a longitudinal design (i.e., only a cross-sectional study design) represents an important limitation. Age at menarche and age at the onset of training are susceptible to recall bias. However, previous investigations have indicated that woman's first menstrual bleed is a widely used measure of puberty timing, a distinct and notable event in their lives, and is well-recalled (Koo and Rohan, 1997; Bosetti et al., 2001; Must et al., 2002). We could not include more sophisticated measurements of body composition (i.e., DEXA scans and pletismography) due to the design of the study and the lack of time and resources to account for these measurements in real-world settings. Only doubly indirect measurements were included (i.e., anthropometry). Body weight satisfaction was not determined with validated questionnaires and is based on the instrument developed by the leading investigator for this study. Finally, other factors that might influence menstrual dysfunctions were not included in our analysis, such as socioeconomic conditions, nutritional assessment, and access to preventive health care, that may influence the timing and progression of puberty and reproductive health (Baxter-Jones and Maffulli, 2002; American Academy of Pediatrics Committee on Adolescence et al., 2006). Although not the ideal variable to represent socioeconomic conditions, we have found that 69.6% of our sample received a salary as a futsal player and receiving a salary was associated with being a premenarche-trained athlete and greater rates of late menarche (data not shown).

Considering the low effect size for almost all the analysis, we cannot provide general clinical/practical guidance and an anthropometric profile based on reproductive-related factors in female futsal players. Rather than that, monitoring these reproductive factors and accounting for their impact on futsal athletes should be done using an individualized approach and considering each athlete's needs. Future research should longitudinally account for the impact of reproductive-related variables in performance and the body composition markers of female futsal players.

CONCLUSION

Brazilian elite futsal players who engaged before the menarche had the menarche significantly later than those who started training after the menarche. Postmenarche-trained players had significant higher body fat and lower ectomorphy rate after controlling for covariates. Early menarche group presented higher sum of six skinfold thickness and endomorphy rate compared to normal and late menarche groups. No differences were found when menstrual periodicity groups and menstrual period, when performance is the best groups, were compared, except for higher femur width in the regular menstrual cycle group compared to the irregular one. Most of the participants of the present study had their menarche age classified as "normal," presented a "regular" menstrual cycle and perceived to perform better during the follicular phase of the menstrual cycle. However, this perception was neither associated with other reproductive-related variables nor differed in anthropometric characteristics.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of ethical reasons.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Research Ethics Committee of the Midwest State University (UNICENTRO), process number 039/2011. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MQ, DS, SF, MN, BP, MT, and EV: concept and design, methodology, the preparation of manuscript, the interpretation of data, formal analysis, and writing – review and editing. DS, TC, DF, and VW: formal analysis, the interpretation of data, writing and review, and the preparation of manuscript. MQ and SF: acquisition of subjects and data and writing and review. All authors contributed to the article and approved the submitted version.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 20 May 2021
doi: 10.3389/fpsyg.2021.623719

Stressors in Indoor and Field Brazilian Soccer: Are They Perceived as a Distress or Eustress?

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OPEN ACCESS

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *30 October 2020*
Accepted: *24 March 2021*
Published: *20 May 2021*

Citation:
Brandão MRF, Polito LF, Hernandes V, Correa M, Mastrocola AP, Oliveira D, Oliveira A, Moura L, Junior MVB and Angelo D (2021) Stressors in Indoor and Field Brazilian Soccer: Are They Perceived as a Distress or Eustress? Front. Psychol. 12:623719. doi: 10.3389/fpsyg.2021.623719

Soccer players inescapably live under stress during the sportive career, and many real-life aspects of soccer situations operate in the ongoing performance. This study's main objective was to elaborate the List of Stressors in Professional Indoor and Field Soccer, a self-report instrument designed to measure the impact of 77 soccer situations upon the sport performance. Participants were 138 indoor and field soccer players from the Brazilian Premier League. Each situation was evaluated on a 7-point scale, ranging from the most negative (−3) to the most positive (+3). Data were analyzed according to the players' perception of the items: distress or eustress and its intensity, and after that, situations perceived as plus −1 and +1 were compared by time in which they were experienced and distributed among five categories established by the literature: Expectations about the Performance, Personal Factors, Competition Aspects, Training Demands, and Relationship with Significant People. Narratives of athletes' experiences were also used to discuss the results. An Exploratory Structural Equation Modeling using Bi-factorial (BI-ESEM) was employed to assess the factor structure. For the total participants, 49 situations were perceived as distress and 28 as eustress. Using the criteria established *a priori*, the distribution was among the five categories in the remaining 32 situations. Differences in perception between less and more experienced players were found in 11 situations. The results revealed that Brazilian professional soccer players experience various stressful situations. These events are important representations of environmental demands and could predict the performance as they are perceived as eustress or distress. Some of these stressful situations are inherent in sport and others adjacent to the sports system or environment. Coach pressure to win and conflicts with teammates are examples of stressors in-sport, family problems and disputes with press or fans are examples of stressors external to the team, also called peripheral opponents, and showed the relative social influence of significant others in soccer performance. We can conclude that the knowledge of the direction of a given stress situation has important practical implications in preparing athletes and helping them face the performance stressors that are part of soccer daily life.

Keywords: eustress and distress, perception, performance, soccer (football), stress

INTRODUCTION

The term *stress* started to be used only at the beginning of the 20th century. Until then, the term was used in physics to describe the force that tends to deform an object. In 1910, Sir William Osler, a British cardiologist, first suggested that stress contributed to coronary heart disease (Robinson, 2018). Since then, stress has moved from a term in physics to a cultural construct, and numerous studies have been carried out to detect the effects of stress on physical and mental health.

Selye (1976), considered the patriarch of research on stress in human beings, refers to a "General Adaptation Syndrome," a syndrome due to the presence of generalized individual manifestations of the organism in the face of a harmful stimulus, adaptation by stimulating the body's defenses, and general because it is produced only by agents that have a widespread effect on large parts of the body.

From the point of view of psychological stress research, the main emphasis of the studies is not on the physiological genesis, but on the psychological genesis of stress, changes in the well-being of individuals, cognitive processes, and appraisal of stressors and their psychological control (Nitsch, 1981; Jones, 1990). According to this conception, the following principles are important: the starting point of the study of stress is in the reciprocal relationship between the individual and the environment, in subjective perception and in the attribution of value judgments that the individual has about the situation of this environment (Folkman and Lazarus, 1984; Lazarus, 2000).

So, what makes a stressful situation is the nature of this circumstance and the interpretation, the way people subjectively perceive and evaluate the situation. This perception depends on the psychic dispositions (attitudes, beliefs, and values) and previous learning. People do not behave passively in the face of environmental stimuli but rather give them personal importance. In the relationship between individual and environment, an intermediate cognitive process is characterized by subjective evaluation, which is considered a decisive point for the emergence of stress (Nitsch, 1981).

In other words, stress is not necessarily debilitating and can facilitate performance. Then, it is vital to research the "directional perception" of the sources of stress, that is, the nature of the individual interpretation of the sources in terms of whether they are positive or negative about the next performance (Jones et al., 1990, 1993; Swain and Jones, 1993; Jones, 1995a; Seligman and Csikszentmihalyi, 2000; Fletcher and Hanton, 2003).

Hypothetically, athletes can report identical sources of stress, but because of variations in "directional perception," they can differ considerably in their interpretations of the consequences on performance. Parfitt et al. (1990) still claim that the "directional perception" of stress sources can predict sports performance better than just the simple indication of a source.

Soccer players, indoor or field, are inevitably exposed to a potential number of stressors that operate on athletic performance during their sports career (Poulus et al., 2020). Professional players are under considerable stress, and they need to compete for a place on the starting lineup and, once they win the place, they must be able to keep it. Low performance in just one game can take the player to the bench in the next round. The risk of injury is always present and can mean the absence of practice for more or less long periods. The athlete must deal with the stress produced by the so-called peripheral opponents, spectators, the press and family members, and the expectations of the coach and his teammates (Apitzsch, 1994; Teipel et al., 1994; Noblet and Gifford, 2002; Mellalieu et al., 2009; Olmedilla et al., 2019).

During training and competitions, soccer players are faced with a series of requirements, stressors, which can vary in terms of the content and intensity of their effect on sports performance (Jones et al., 1993; Swain and Jones, 1993; Jones, 1995a; Brandão, 2000; De Rose Junior et al., 2004; Zahariadis et al., 2006; Thelwell et al., 2008, Main and Grove, 2009; Garcia-Maás et al., 2010). But, for Urhausen et al. (1998) and De Rose Junior et al. (2004), it is not only during training and competitions that stressful situations occur. They also appear in events inside and outside of sport and influence an athlete's mental and physical readiness. Thus, an important aspect pointed out in evaluating sport stressors concerns the sources of stressful situations and the perception of these sources' direction and intensity. The psychological and physiological demands in soccer associated with training, competitions, and the social organization of sport show that performance is a complex phenomenon affected by factors inherent to the sport modality and environmental factors.

A literature review (Cohn, 1990; Scanlan et al., 1991; Samulski and Chagas, 1992; De Rose Junior and Vasconcellos, 1993; VanYperen, 1994; Brandão, 2000; De Rose Junior et al., 2004) showed that there are 5 major sources of stress inherent to various sports: expectations about performance, personal factors, aspects of competition, physical demands, and relationships with significant people and traumatic experiences. The category expectations about performance is composed of two subcategories: goals and pressure. The goal refers to the athlete's ambition to achieve a certain sporting result and the pressure, the demands of the media, himself, and others that indicate performance expectations, pressure to meet the established goals, "obligation" to win a certain game and to achieve expected results. Personal factors refer to the demands (costs or psychological benefits) of sports practice. This category includes the athlete's disposition, his psychological and organic state, and other aspects of professional practice such as the employment contract. The competition aspects refer to the events that commonly occur during the competition. A negative stress response occurs when the athlete has feelings or thoughts of concern about some aspect of the game, the conditions of the field, the crowd, the press assessment, etc. Physical demands refer to the role that factors inherent to the sporting event play in the stress process. If the athlete does not have a personal fitness to deal with the demands of training and competitions, consequently there is a risk of failure or a decrease in performance. Finally, the dimension relationship with significant people refers to the extent and nature of the bonds with people that are significant for athletes and that influence their performance. These people are fully involved in the structure, dynamics, and social environment of the sport practiced. Teipel et al. (1994), in a study with soccer players, showed that previous defeats, the influence of the fans, and the unexpected results of the opposing team were motivators and, therefore, facilitators of sports performance. On the other hand, being physically weak, uncomfortable competitive conditions, failed actions at the start of competitions, conflicts with the coach, problems with the referees, the coach's continued criticism from the bench, failed actions, and the negative criticism of teammates was harmful to the performance.

If there is a positive or negative impact of these stressors on soccer players' sports performance, they need to be investigated. So, the purpose of this study was six, including (a) development of a *List of Stressors in Professional Indoor and Field Soccer* to facilitate the identification of situations that can cause stress in professional indoor and field players, (b) confirm if the stressful situations can be perceived as both distress and eustress, (c) identify the situations perceived as distress and eustress, (d) check which items make up the five previously established categories (*Expectations about the Performance, Personal Factors, Competition Aspects, Training Demands, Relationship with Significant People*), (e) examine the differences in the perception of the situations by age, and time as professional, and (f) assess the factor structure of the list.

MATERIALS AND METHODS

Participants

A total of 138 indoor and field male soccer players (17 goalkeepers, 41 defenders, 47 midfielders, and 33 forward) from the Brazilian Premier League participated in the study (age = *24.46* years, *SD = 3.93*; sports experience = *11.25* years, *SD = 4.61*, years as a professional player = *5.62* years, *SD = 3.77*, and years of soccer practice = *11,68*, *SD = 4,71* years). The participants comprised players from four different clubs, including Palmeiras, Grêmio, Internacional, and Paulista (Jundiaí). As professional players, they train an average of 10 h per week of football *per se* and 8 h of physical preparation. In addition, in the main championship of the country they compete twice a week, on Wednesdays and Sundays. It is essential to highlight that from all the participants, 18 field soccer players had played for the Brazilian National team.

Measurements

(1) Socio-demographic and background information.

We assessed age, sports experience, years as a professional player.

(2) Measurement of the stress situations in indoor and field soccer.

List Development

The list of football situations was designed based on the Life Events Checklist, the dominant method used by researchers in the last 50 years (Dohrenwend, 2006), defined as occurrences, fundamentally critical environmental incidents, that were likely to bring about readjustment-requiring changes in people's usual activities. Moreover, it was elaborated considering the theoretical review of stress in soccer (Frester, 1976; Samulski and Chagas, 1992, 1996; Teipel, 1993; Brandão, 2000). To develop an initial list of soccer situations, a focus group composed of two specialist soccer coaches and five professional players (three field soccer and two indoor soccer) besides the main researcher of this study was created. The focus group's objective was to help reflect not only on the situations they considered important but also on the different points of view presented and the strength of each situation to be part of the list of stressful situations in soccer. The group was gathered three times to achieve this goal. The focus group listed 72 situations that ranged from the regular activities involved in the football environment, training, competitions, on the one hand, to the relationship with significant people, such as coaches, referees, teammates and the press, on the other.

After that, five event categories defined *a priori* according to the literature review were used to classify the 72 items. Some examples of events for each of the five categories are: for Category 1: *Expectations about the Performance* (Being the favorite, Coach pressure to win); Category 2: *Personal Factors* (Not sleeping well the night before the competition, Being with the contract already due or close to its maturity date); Category 3: *Competition Aspects* (Playing against a hostile audience, Not scoring a goal that was practically attained); Category 4: *Training Demands* (Being blatantly dribbled during tactical training, training in two periods); Category 5: *Relationship with Significant People* (Having problems or conflicts with the coach, Being jeopardized by the referees).

For the structuring of a procedure that would provide the recording of the conditions of the situations by the athlete, it was interesting to know not only which situations were experienced as distress or eustress but, at the same time, how intensely each situation could act as a disturbance or, on the contrary, as a stimulus to the athletic performance. To this end, a seven-level scale was developed, with three dimensions (eustress, distress, and a performance-neutral dimension). Each dimension had three levels of intensity. Thus, 1, 2, 3 identify the positive or negative impact intensity of the situation to the performance, as follows: +1 (a small amount of positive impact); +2 (a moderate amount of positive impact); +3 (a huge amount of positive impact); −3 (a huge amount of negative impact; −2 (a moderate amount of negative impact); −1 (a small amount of negative impact). The number 0 is the center of the scale and means that the situation neither stimulates positively nor negatively the performance.

The events list was tested in an exploratory study with 24 players to verify the clarity of the items' instructions and phrasing, the item suitability, and the possibility of inclusion, revision, or rejection of each item in the item pool. Seven item events that presented ambiguous responses and one item that referred only to goalkeepers were neglected. Thirteen items were included to increase the instrument's credibility. The inclusions were based on the testimonies of the players obtained during the application of the exploratory project. This process generated a second version of the list composed of 77 events.

Then, an initial revision of the second version was made by a panel of judges, composed by a Ph.D. in Sport Psychology, specialist in the study of stress in sport and especially in soccer, by the coach of the Brazilian Soccer National Team and his assistant, the goalkeeper coach of one of the evaluated teams, a Ph.D. in sports training and the main researcher of the study that worked with high performance professional soccer teams, including the Brazilian team. Their suggestions were primarily regarding the understanding of the response to items by players with a low level of education. They recommended using graphic symbols ("faces") that represented the perception of the direction and intensity of stress. Thus, the following symbols appeared in the test body:☹☹☹, ☹☹, ☹, 😐, ☺☺, ☺☺☺ which represent −3, −2, −1, 0, +1, +2, +3, respectively.

Then, these procedures generated the final "*List of Stressors in Professional Indoor and Field Brazilian Soccer*" of this study, which consists of 77 soccer events and five categories, seven items for Category 1; six items for Category 2; 40 items for Category 3 (subdivided into three groups: opponents six items; imminent or real failure eight items; aspects of the game 26 items); 14 items for Category 4; and 10 items for Category 5. It is important to highlight that the item pool was developed so that the language was common to both indoor soccer players and field soccer players. The categories of stressors, definition, and list of the 77 events are shown in **Table 1**.

Data Collection and Procedures

The study was conducted according to international guidelines for ethical principles of scientific research with human beings. The study procedures of this research were also approved by the Human Research Ethics Committee of the University São Judas Tadeu. Indoor and field soccer players from the Brazilian First Division were invited to participate in this study. Upon obtaining participants' written informed consent, the data were collected, individually, outside training hours, in pre-season periods (preparation period before the competitive period). Participants were encouraged to read each situation and provide honest responses about their effect on the performance and its magnitude. Special emphasis was placed on confidentiality and participation was not mandatory.

After the list evaluation, all athletes undertook a semi-structured interview. The main objective of the individual interviews was to understand the perception of stressful situations from what each player experiences and to give him the possibility to talk about that experience. The interviews also explored how well the items captured the athletes' experiences about the item's content. Interviews were audio-recorded and then transcribed verbatim.

Analysis

All items on the stressor list were analyzed in descriptive statistics and considered if they were perceived as a distress or eustress. Subsequently, a first analysis of the data was made according to the following criteria: the items evaluated between −1 and −3, and +1 and +3 were classified according to five stressors categories defined *a priori*. This interval was chosen because the objective of the study was to identify situations that had a negative or positive impact on performance, and situations assessed close to neutral indicate that according to the perception of the Brazilian players they do not interfere in any way to the performance and, therefore, can be excluded. The one-way analysis of variance (ANOVA) and a *post hoc* test Tukey was then used to compare the players by age (younger, average, and older players) and time as a professional. The level of significance adopted was 0.05.

An Exploratory Structural Equation Modeling using Bi-factorial (BI-ESEM) was employed to assess the factor structure. We chose to use a BI-ESEM model to allow estimates of direct relationships between items and specific and global factors; thus, it is possible to separate the variation attributed to specific factors, from that attributed to the general factor (Holzinger and Swineford, 1937).

Bi-factorial models assume that the covariance between a set of items can be explained by a set of orthogonal factors, including global factor (G-factor; in this case they would be 2 global factors) and specific factors (S-factor). The recent development of bi-factorial rotation for EFA has made it possible to incorporate bi-factorial modeling into the ESEM framework. In BI-ESEM, the G factors were specified separately, outside the rotation process (Arens and Morin, 2017; Howard et al., 2018; Marsh et al., 2020).

To assess the levels of reliability of the latent variables, it was used and the Composite Reliability (CR). Values above 0.7 are considered adequate (Hair et al., 2014).

RESULTS

The mean and standard deviation of the 77 items of the list of stressors are shown in **Table 2**. To better view the results, the events were plotted into a figure (**Figure 1**) according to the perception of distress (A) or eustress (B). As one can observe, 49 soccer events were perceived as distress and 28 as eustress.

The soccer events evaluated between −1 and −3, and +1 and +3, comprising a total of 32 items, were selected to be analyzed. In **Table 3**, it is possible to observe the number of athletes who have chosen each negative (A) or positive (B) dimension of the 32 situations. Two items draw attention, numbers 1 (*Not being in good shape*) and 75 (*Lack of group cohesion*), experienced as having a large amount of negative impact for 111 and 100 players, representing 80 and 72% of the total athletes, respectively. Other items that have a high negative impact on performance for more than 50% of the players were: 9 (*Having problems or conflicts with the coach*), 10 (*Having problems or disputes with the teammates*), 35 (*Losing by a dilated score*), and 59 (*Playing injured*). On the other hand, items 6 (*Establishing high goals*) and 40 (*Playing a derby*) were considered as having a high positive impact on the performance for 87 and 82% of the total athletes. The other items that have a high positive impact were: 19 (*Playing at home*), 20 (*Assuming responsibilities inside the team*), 25 (*Some other team wanting to book you*), 32 (*Doing a speed training*), 34 (*Stretching*), 49 (*Self-pressure to play well*), and 52 (*Knowing in advance that you are going to play*).

The 32 situations were then classified according to the five categories defined *a priori* (Category 1: Expectations about the Performance, 4 items; Category 2: Personal Factors, 5 items; Category 3: Competition Aspects, 12 items; Category 4: Training Demands, 6 items; Category 5: Relationship with Significant

TABLE 1 | Categories of stressors, definition, and list of the 77 events.

Category	Definition	Situations
(1) Expectations about the performance	Refers to the situations related to goals and pressure. The goal refers to the athlete's ambition to achieve a certain sporting results and the pressure to meet the established goals, "obligation" to win a certain game and achieve expected results.	(5) Being the favorite (6) Establishing high goals (20) Assuming responsibilities inside the team (22) Press pressure (39) Pressure of the other people to win (49) Self-pressure to play well (51) Coach pressure to win
(2) Personal factors	Refers to the demands (costs or psychological benefits) of sports practice. This category includes the athlete's disposition, his psychological and organic state, and other aspects of professional practice such as the employment contract.	(1) Not being in a good shape (3) Being very nervous (4) Not sleeping well the night before the competition (24) Being with the contract already due or close to its maturity (25) Some other team wanting to book you (73) Lack of psychological preparation
(3) Competition aspects (aspects of the game)	Refers to the events that commonly occur during the competition. A negative stress response occurs when the athlete has feelings or thoughts of concern about some aspect of the game, the conditions of the field, the crowd, etc.	(2) Staying in the bench and not playing during the game (18) Playing against a hostile audience (19) Playing at home (21) A protracted competition (26) Playing at night (27) Playing in an empty stadium (28) Playing in a rough ground/court (31) Playing in the afternoon (40) Playing a derby (44) Being in the bench and entering during the game (45) Knowing that you are playing minutes before the game starts (52) Knowing in advance that you are going to play (55) Being isolated in a facility on the eve of the match (56) Getting a yellow card (57) Decision by sudden death (58) Playing in the rain (59) Playing injured (60) Playing in the morning (63) Being advised that you are not going to play just before the game (67) Wrong plays in decisive moments (70) Being blatantly dribbled during the game (71) Playing under very warm climate (72) Wrong plays at the end of the game (74) Inadequate technical and tactical preparation (76) Playing an improvised position
(3) Competition aspects (imminent or real failure)	Refers to the situations in which the player has imminent possibilities of failure or which involve a real failure.	(8) Previous defeats (12) Defeats in the beginning of a championship (33) When your team suffers a goal (35) Losing by a dilated score (36) Not scoring a goal that was practically attained (37) Scoring a goal against your own team (38) Losing a penalty (65) Finishing the first half with an adverse score
(3) Competition aspects (opponents' aspects)	Refers to situations related to opponents in any aspect, behaviors, previous negative experiences, etc.	(7) Playing against unknown opponents (11) Being perplexed with the good performance of the opponents (14) Great superiority of the opponents (17) Having lost previously to the same opponent (30) Being ridiculed by opponent during the game (77) Playing against and aggressive opponent
(4) Training demands	Refers to the role that factors inherent to the sporting event play in the stress process, if the athlete does not have a personal aptitude to deal with the demands of training and competitions, there is a risk of failure or a decrease in performance.	(16) Having bad lodgings and facilities (29) Being blatantly dribbled during tactical training (32) Doing a speed training (34) Stretching (41) Doing a tactical training 1 day before the game (42) Excessive physical training (43) Training early in the morning (47) A long trip (48) Training in 2 periods (53) A hard warm up before the game (62) Doing too much weight exercise (66) A light warm up before the game (68) Pre-season out of the routine premises (69) Too much resistance training

(Continued)

TABLE 1 | Continued

Category	Definition	Situations
(5) Relationship with significant people	Refers to the extent and nature of bonds with people who are significant to athletes and who influence their performance. These people are fully involved in the structure, dynamics, and social environment of the sport practiced.	(9) Having problems or conflicts with the coach (10) Having problems or conflicts with the teammates (13) Being scolded by a teammate during the game (15) Being jeopardized by the referees (46) Being scolded by the coach during the mid-game interval (50) Press behavior before the game (54) Being scolded by the coach during the pre-game talk (61) Conflicts with the family (64) Receiving threats from the referee during the game (75) Lack of group cohesion

TABLE 2 | Mean and standard deviation of the 77 items of the list of stressors.

N = 138	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
x	−2.73	−1.36	−1.73	−1.79	0.69	2.8	0.28	−0.43	−1.91	−1.91	0.27	−1.20	0.81	0.54	−1.77	−1.64
SD	0.49	1.45	1.45	1.1	1.55	0.61	1.2	1.59	1.48	1.32	1.33	1.44	1.36	1.78	1.3	1.32
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
x	−0.70	0.88	2.30	2.28	0.37	−0.17	−0.70	−0.80	2.15	1.28	−1.03	−1.78	−0.31	−0.05	0.59	2.25
SD	1.72	1.63	1.19	1.08	1.39	1.40	1.19	1.49	1.21	1.45	1.38	1.31	0.80	1.32	1.37	1.28
	33	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**
x	−0.95	2.16	−2.20	−1.37	−1.72	−1.67	−0.14	2.72	−0.12	−0.05	0.68	−0.12	0.74	0.19	−1.20	0.99
SD	1.51	1.22	1.24	1.24	1.21	1.18	1.20	0.86	1.46	1.83	1.43	1.71	1.75	1.44	1.13	1.40
	49	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**
x	2.45	−0.09	1.13	2.53	−0.25	0.08	2.08	−0.75	−0.14	−0.10	−2.22	−0.59	−1.67	−0.54	−2.07	−0.86
SD	1.03	0.69	1.55	1.05	1.64	1.36	1.25	1.03	1.21	1.51	1.13	1.41	1.22	1.58	1.21	1.14
	65	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**			
x	−0.57	−0.47	−1.22	1.23	0.86	−0.31	−0.95	−1.04	−1.54	−1.98	−2.43	−0.40	0.07			
SD	1.37	1.54	1.19	1.48	1.70	0.87	1.30	1.12	1.16	1.07	0.97	1.36	1.38			

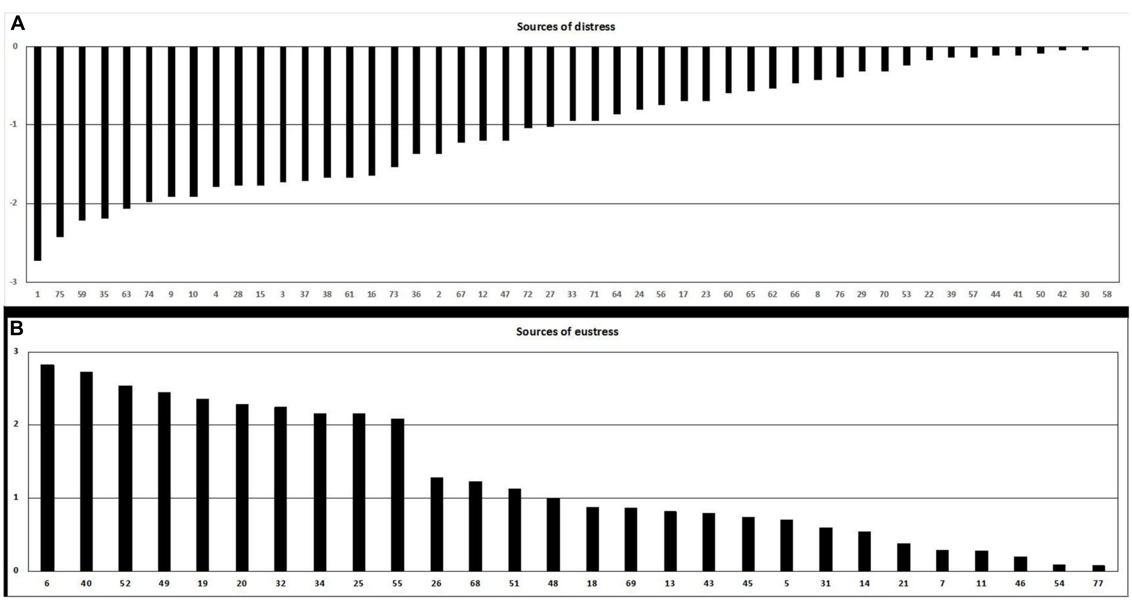

FIGURE 1 | List of stressors perceived as distress **(A)** or eustress **(B)**.

TABLE 3 | Number of athletes who have chosen each negative, neutral, or positive dimension of the 32 situations (in yellow the negatives, and in green the positive situations chosen by 50% or more).

	1	**2**	**3**	**4**	**6**	**9**	**10**	**15**	**16**	**19**	**20**	**25**	**26**	**28**	**32**	**34**
−3	111	44	52	47	–	81	76	55	38	–	–	1	1	55	1	–
−2	21	19	34	27	–	14	12	19	38	2	–	–	1	21	–	1
−1	6	27	31	36	–	20	21	37	32	3	–	1	2	37	–	2
0	–	39	14	27	3	14	25	24	25	11	9	20	62	22	11	11
+1	–	4	3	1	2	4	3	–	1	9	14	20	8	–	15	19
+2	–	5	1	–	13	4	1	2	1	30	39	14	15	3	23	20
+3	–	–	3	–	120	1	–	1	3	80	76	82	49	–	88	85
	35	36	37	38	40	48	49	51	52	59	61	63	68	69	73	75
−3	82	35	40	41	1	–	1	2	7	69	45	67	4	2	38	100
−2	9	20	17	19	–	2	–	3	5	24	25	10	4	9	25	18
−1	31	29	33	42	–	5	4	9	3	33	28	16	5	17	47	17
0	10	46	47	35	5	54	2	38	16	2	39	38	75	41	26	2
+1	4	8	1	1	8	20	17	25	5	7	–	2	4	19	1	1
+2	2	–	–	–	11	23	29	25	10	3	–	3	10	25	–	–
+3	–	–	–	–	113	34	85	36	92	–	1	2	36	25	1	–

People, 5 items). The 32-item instrument showed good reliability (CR = 0.74). We assessed the CR of each category that presented the following results: CR = 0.65 for Expectations about the performance; CR = 0.51 for Personal factors; CR = 0.64 for Competition aspects; CR = 0.62 for Training demands; and CR = 0.84 for Relationship with significant people. The soccer events are plotted in **Figure 2**, from the most negative to the most positive impact on the performance.

As shown in **Figure 2**, a wide variability of the performance's impact exists among the stress categories. In Category 1, all the events were perceived as positives, and in Category 5, all the events were perceived as negatives. In Categories 2, 3, and 4, some of the events were perceived as negative, while others were perceived as positive. Special attention was given to Category 3 that was divided into three as previously described: opponents, imminent or real failure, and aspects of the game. None of the opponents' soccer events reached the established result criterion regarding average being from −1 to −3 or +1 to +3.

These 32 situations were compared between age (younger, average, and older players), and time as professional (less experience, average, and more experience players). The results by age can be observed in **Table 4** and the significant items in **Figure 3**, and by time as professional in **Table 5** and the significant items in **Figure 4**. Compared by age we can observe differences ($p < 0.01$) in 10 situations (3, 4, 19, 25, 34, 35, 36, 51, 59, and 73); younger players tend to evaluate situations as more negative or more positive to performance when compared mainly with older players. Compared by time as professionals, we can observe differences ($p < 0.01$) in eight situations (3, 4, 19, 25, 36, 51, 59, and 73) and notice the same trend as before: less experienced players tend to evaluate situations as more negative or more positive to performance when compared mainly with more experienced players.

A structural model with the 32 items that had the most significant impact (negative or positive) on performance and classified according to the five categories was used to previously evaluate the Field and Indoor Professional Stressors List's factor structure. Analysis of the players' responses leads us to believe that the 32 items of the list that had the most impact (negative or positive) on the performance can be explained by two distinct latent variables. The stress items were divided by category; however, within the same category, some items were perceived as eustress while others as distress (although the items were divided by category, it was not possible to conclude based only on the category which one generates stress or eustress). The Composite Reliability value was 0.88 for distress and 0.78 for eustress. Based on the assumption that there is a solution for the set of items with two global factors (distress and eustress) and specific factors (the categories in which the items were classified), a Bi-factorial Exploratory Structural Equation Modeling (BI-ESEM) was employed to assess the factor structure.

The adequacy of the model was assessed by the adjustment meanings Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI). According to the literature (Brown, 2015), RMSEA and SRMR values must be less than 0.08, CFI and TLI values must be above 0.90, or preferably 0.95.

The assumption of normality of the data was not satisfied using the Shapiro–Wilk test and the estimation methods were chosen according to the results of the Mardia's coefficient for data that violate the assumption of multivariate normality (coefficient of multivariate kurtosis = 36.08). The method of extracting the Weighted Least Squares Adjusted by Average and Variance (WLSMV) was implemented in a polychoric data matrix, considering the ordinal nature of the data (Holgado-tello, 2015).

The model's adjustment indexes are acceptable (Chi-Square = 354.77; df = 288; RMSEA = 0.041; CFI = 0.966; TLI = 0.945; SRMR = 0.059). However, the G-factors were not well defined by strong and significant loads (**Table 6**). For illustration purposes, we present the results of the path diagrams of model in **Figure 5**.

In the Relationship with Significant People category, except for item 15, all the others had significant loads above 0.40 in

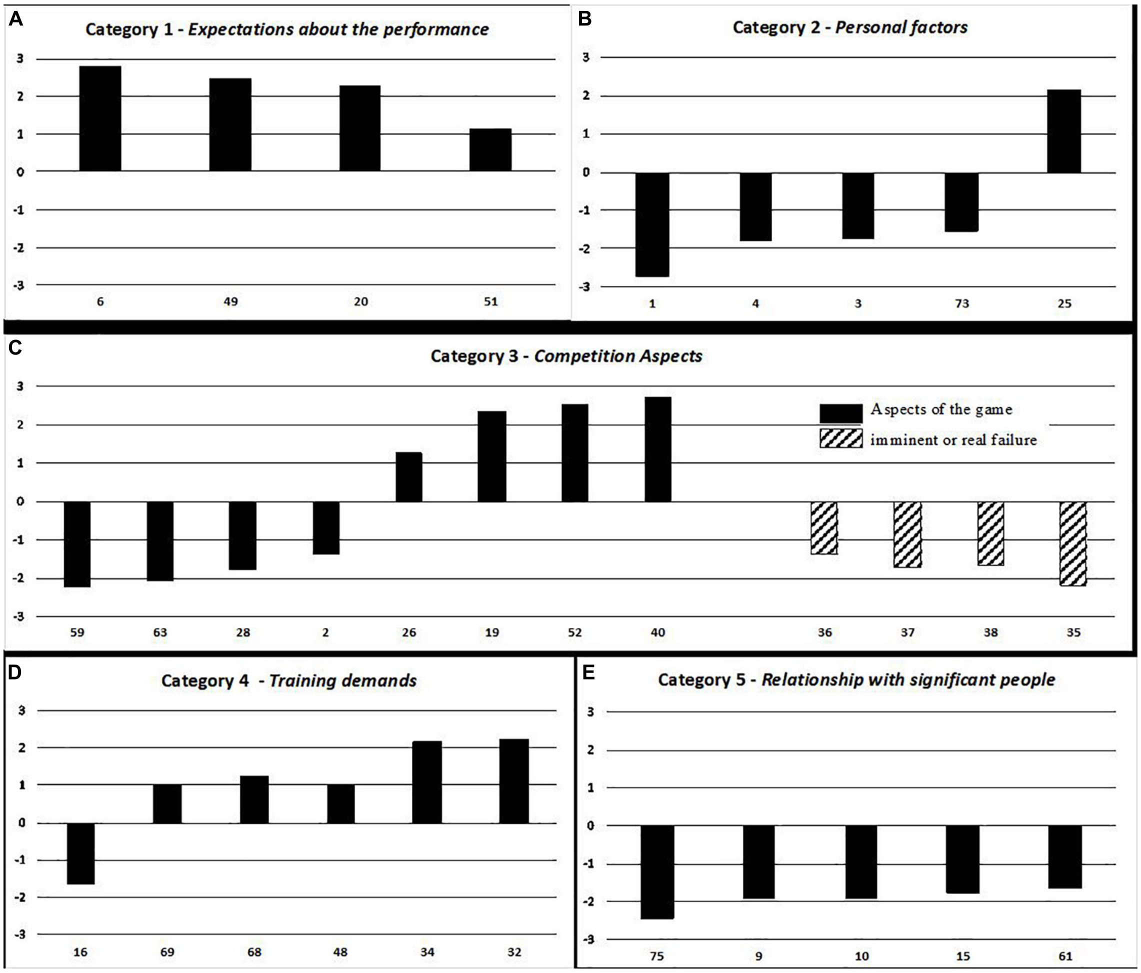

FIGURE 2 | List of soccer event stressors by categories of stress, *Expectations about Performance* **(A)**, *Personal Factor* **(B)**, *Competition Aspects* **(C)**, *Training Demands* **(D)**, and *Relationship with Significant People* **(E)**.

the G-factor. In the Training Demand category, items 16, 32, 34, and 69 were better defined in the G-factor, and item 68 had an acceptable factor load in its respective factor. In the category Aspects of the Competition, items 21, 28, 35, 36, 37, 38, 59, and 63 showed high levels of specificity associated with the S-factor ranging between 0.45 and 0.75 and the other items (21, 19, and 26) presented significant loads, but below the desired level. In the Expectations about the Performance category, items 51 and 6 showed factorial loads of 0.51 and 0.64 in factors S and G, respectively. In the Personal Factors category, except for item 1, all items presented significant loads, however, weak in the respective S-factors, and were poorly defined in the G-factor.

DISCUSSION

The aims of this study were six, including (a) develop a List of Stressors in Professional Indoor and Field Soccer to facilitate the identification of situations that can cause stress in professional indoor and field players, (b) confirm if the stressful situations can be perceived as both distress and eustress, (c) identify the situations perceived as distress and eustress, (d) check which items make up the five previously established categories, (e) examine the differences in the perception of the situations by age, and time as professional, and (f) assess the factor structure of the list.

The conception considered initially for elaborating the list of stressful situations postulated that the level of stress of a soccer player, indoor or field, is expressed by the intensity of impact on the performance caused by events in the athletes' sportive lives. Another important point is that the events are not positive or negative *per se*. Still, these soccer events are objective occurrences experienced by the players with enough intensity to impact their performance. During training and competitions, soccer players face a series of requirements, called stressors, which can vary in terms of the content and intensity of their effect on sports performance. Nevertheless, training and competitions are only a part of the player's sporting experience; according to Noblet and Gifford (2002), other events directly and indirectly related to them, such as family, contract negotiations, transfers, injuries,

TABLE 4 | 32 items for younger (≤22 years), average (23–27 years), and older (≥28 years) players.

		1	2	3	4	6	9	10	15	16	19	20
≥28	*x*	−2.73	−1.00	−1.73	−1.09	2.82	−1.73	−1.73	−1.64	−1.27	2.18	2.27
	SD	0.65	1.34	1.01	1.45	0.60	1.35	1.49	1.12	1.35	1.08	1.19
23–27	*x*	−2.80	−1.48	−1.56	−1.76	2.76	−1.88	−1.68	−1.76	−1.44	2.44	2.48
	SD	0.5	1.22	1.68	1.22	0.66	1.39	1.31	1.23	1.15	0.91	0.82
≤22	*x*	−3.00	−0.91	−2.64*	−2.55*	3.00	−2.36	−2.45	−2.09	−2.00	2.82*	2.36
	SD	0.01	1.76	0.67	0.82	0.01	1.03	0.93	1.04	1.09	0.60	0.92
		25	**26**	**28**	**32**	**34**	**35**	**36**	**37**	**38**	**40**	**48**
≥28	*x*	1.36	0.82	−1.18	2.09	2.18	−1.55	−0.73	−1.82	−1.64	3.00	0.82
	SD	1.43	1.40	1.53	1.38	1.08	1.29	1.27	0.98	1.12	0.01	1.33
23–27	*x*	2.36	1.36	−1.68	2.12	1.84	−2.12	−1.24¥	−1.48	−1.57	2.76	1.08
	SD	1.11	1.70	1.18	1.48	1.46	1.30	1.30	1.36	1.29	0.72	1.32
≤22	*x*	2.73*	1.27	−1.55	2.55	2.73*	−2.36*	−2.33*	−1.89	−1.89	2.45	1.64
	SD	0.47	1.35	1.57	0.82	0.47	1.12	1.12	1.17	1.17	1.81	1.43
		49	**51**	**52**	**59**	**61**	**63**	**68**	**69**	**73**	**75**	
≥28	*x*	2.82	0.09#	2.64	−1.36	−1,91	−1.64	1.09	1.36	−1.27	−2.27	
	SD	0.40	1.81	0.92	1.50	1.04	1.29	1.38	1.75	1.19	1.10	
23–27	*x*	2.40	1.72	2.36	−2.08	−1.48	−2.44	0.64	1.20	−1.16¥	−2.56	
	SD	1.26	1.24	1.11	1.35	1.56	1.12	1.41	1.29	1.46	0.82	
≤22	*x*	2.91	2.27*	−2.91	−2.82*	−2.09	−2.27	1.64	1.45	−2.27*	−2.73	
	SD	0.30	0.79	0.30	0.40	1.22	1.10	1.63	1.44	0.90	0.65	

** difference between ≥28 and ≤22, ¥ difference between 23–27 and ≥28, # difference between ≤22 and 23–27.*

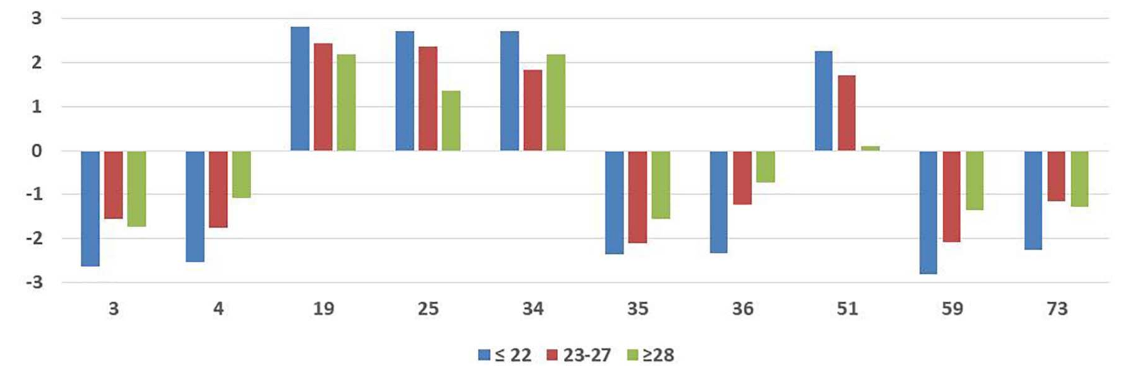

FIGURE 3 | Significant items for younger (≤22 years), average (23–27 years), and older (≥28 years) players.

and rehabilitation, also need to be considered in the investigation of the sources of stress. So, the list was formed by situations that can be classified as (a) inherent in the competitive process, that is, that are directly part of the competition process, are related to the individual or the environment, and (b) adjacent to the competitive process, which happen in everyday life and are independent of the competitive process, such as family problems (De Rose Junior et al., 2004).

Our study confirms that soccer is a challenging environment composed of a spectrum of inherent and adjacent situations, which can impact the performance of the players in a positive (eustress) or negative (distress) way depending on how athletes perceive the situations. In summary, it refers to the extent to which soccer players label the intensity of the cognitive and somatic symptoms of stress experienced in a debilitating-facilitative continuum. This agrees with the studies made by Pargman (1986), Anshel (1990), Jones et al. (1990, 1993), Samulski and Chagas (1992, 1996), Jones and Swain (1995), Jones (1995b), Ntoumanis and Biddle (1998), Brandão et al. (2002), Aschbacher et al. (2013), Kung and Chan (2014), Hargrove et al. (2015), Madigan et al. (2017), McCormick et al. (2018); and have shown that it is not enough to analyze whether certain situations generate stress or not, but mainly, analyze the directional perception of the situations, that is, the nature of interpretation of situations in terms of having a positive or negative relationship with the subsequent performance.

Thus, it is not surprising that the stress phenomenon in sport has been considerably studied in the past decades since high

TABLE 5 | 32 items for less (−3 years), average (4–8 years), and more (+9 years) experienced athletes.

		1	2	3	4	6	9	10	15	16	19	20
≥9	*x*	−2.81	−1.09	−1.63	−1.27	2.72	−1.81	−1.90	−1.63	−1.27	2.00	2.27
	SD	0.60	1.30	1.02	1.42	0.64	1.07	1.22	1.28	1.34	1.09	1.19
4–8	*x*	−2.76	−1.28	−1.68	−1.60¥	2.76	−2.00	−1.68	−1.76	−1.52	2.52	2.40
	SD	0.52	1.24	1.70	1.22	0.66	1.38	1.31	1.16	1.12	0.87	0.86
≤3	*x*	−3.00	−1.18	−2.63*	−2.72*	3.00	−2.36	−2.45	−2.09	−2.00	2.81*	2.36
	SD	0.01	1.83	0.67	0.64	0.01	1.02	0.93	1.04	1.09	0.60	0.92

		25	26	28	32	34	35	36	37	38	40	48
≥9	*x*	1.63	0.81	−1.18	2.09	2.27	−1.72	−0.90	−1.72	−1.63	3.00	0.81
	SD	1.43	1.40	1.53	1.37	0.90	1.34	1.44	1.19	1.28	0.01	1.32
4–8	*x*	2.28	1.56	−1.64	2.12	1.80	−2.04	−1.04¥	−1.38	−1.52	2.68	1.08
	SD	1.13	1.68	1.41	1.48	1.50	1.30	1.32	1.24	1.20	0.80	1.32
≤3	*x*	2.72*	1.00	−1.81	2.54	2.72	−2.36	−2.33*	−1.88	−2.11	2.45	1.63
	SD	0.46	1.26	1.07	0.82	0.46	1.12	1.11	1.26	1.16	1.80	1.43

		49	51	52	59	61	63	68	69	73	75
≥9	*x*	2.72	−0.09#	2.36	−1.81	−1, 8.	−1.72	1.09	1.00	−1.36	−2.36
	SD	0.46	1.57	1.20	1.25	1.16	1.34	1.37	1.54	1.20	0.80
4–8	*x*	2.40	1.72	2.48	−2.00	−1.52	−2.36	0.84	1.24	−1.04¥	−2.52
	SD	1.25	1.24	1.00	1.38	1.53	1.15	1.37	1.36	1.39	0.96
≤3	*x*	2.91	2.27*	2.90	−2.82*	−2.36	−2.45	1.18	1.45	−2.45*	−2.73
	SD	0.30	0.79	0.30	0.40	1.03	1.04	1.89	1.44	0.82	0.65

** difference between ≥9 and ≤3, ¥ difference between 4–8 and ≥9, # difference between ≤3 and 4–8.*

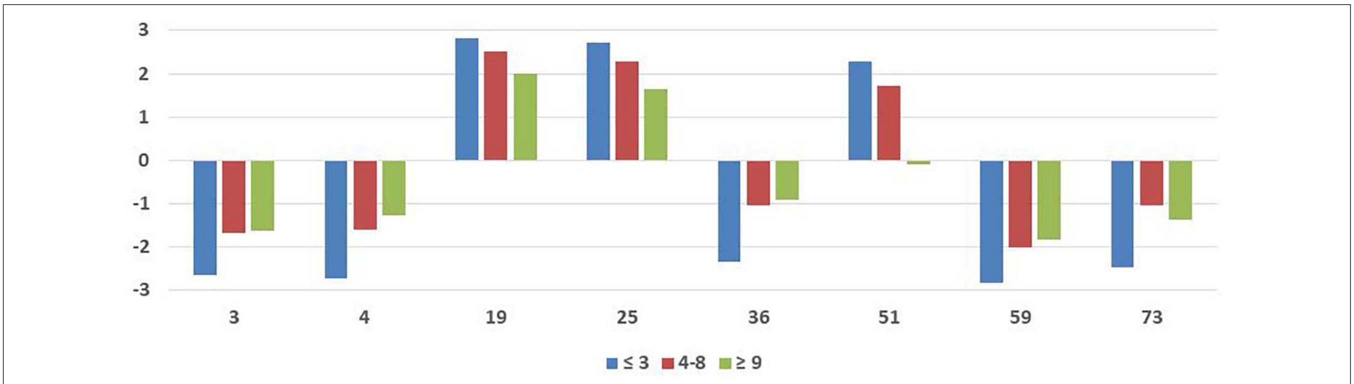

FIGURE 4 | Significant items for less (–3 years), average (4–8 years), and more (+9 years) experienced athletes.

performance sport is characterized by a demand to perform at optimal levels in often intense pressure situations that can interfere with the athletes' actions, thoughts, and feelings (Brandão, 2000). By its nature, high-performance sport is highly competitive and invariably generates stress in athletes. To Scanlan et al. (1991), with rare exceptions, elite athletes experience stress during their long and arduous sports career to achieve sports excellence, and that would be extremely hard for an athlete to invest so much time and energy in such a challenging environment without feeling any stress or pressure.

However, there is one aspect to consider, as we can observe a large dispersion of responses in some situations (**Table 2**) which leads us to affirm that the player's perception in the experience of a particular situation is not uniform, indicating that part of them experience the situation as a performance stimulus and another part as having a negative impact in the performance. These results confirm a classical study of Frester (1976) that considers that equal conditions are often experienced and psychically elaborated differently. This understanding leads to the need for an individual analysis of the subjective perception of the situations.

However, it is interesting to highlight the situations perceived negatively and positively by more than 50% of players (**Table 3**). The most intensely disturbing situations chosen by players showed firstly how the relationship with significant others can impair the performance of the players, which is in accordance with Ommundsen and Vaglum (1991), Horn (2008), Weinberg and Gould (2008), Kristiansen et al. (2012), and Chan et al. (2019), which studies showed that one of the main sources of

TABLE 6 | Standardized factorial loads of the model.

	EP	PF	CA	TD	RE	G-Factor	Uniquenesses
EP06	−0.315					0.642	0.296
EP20	0.037					0.101	0.750
EP49	−0.270					0.157	0.804
EP51	0.511					0.083	0.726
PF01		0.741				0.119	0.209
PF03		0.377				0.150	0.603
PF04		0.271				0.135	0.654
PF25		−0.320				0–367	0.539
PF73		0.389				0.163	0.564
AC02			0.454			0.260	0.682
CA19			−0.025			−0.117	0.576
CA26			−0.120			−0.305	0.579
CA28			0.571			0.323	0.502
CA35			0.665			0.274	0.341
CA36			0.636			−0.359	0.313
CA37			0.705			−0.446	0.126
CA38			0.754			−0.266	0.208
CA40			−0380			0.279	0.676
CA59			0.560			0.140	0.452
CA63			0.628			0.288	0.157
CA52			0.583			0.014	0.014
TD16				−0.090		0.413	0.577
TD32				−0.051		0.365	0.505
TD34				−0.459		0.552	0.421
TD48				−0.266		0.130	0722
TD68				0.542		0.242	0.526
TD69				0.253		0.462	0.450
RE09					0.522	0.622	0.135
RE10					0.568	0.596	0.131
RE15					0.183	0.289	0.649
RE61					0.185	0.432	0.539
RE75					−0.269	0.527	0.218

EP, expectations about performance; PF, personal factor; CA, competition aspects; TD, training demands; RE, relationship with significant people.

negative stress in sport are the reprimands and criticism of the coaches. A poor relationship between the coach and their players, and between players among themselves, can influence the players' cognitive, emotional, and behavioral processes and how it has consequences in the performance. One player explained that situation: "*Under the command of T., the team lost 5 games in a row. Explosive and even fearless, he soon became incompatible with the team.*"

Secondly is the decrements in performance that arise from playing under condition of injury or not being in a good shape. According to Hägglund et al. (2013), Foster et al. (2001), and Nobari et al. (2020) the workouts' poorly intensity and volume, the inadequate total load of daily training, training monotony, strain, and accumulated fatigue can lead to injuries and poor physical conditions and interfere on the players' perceived ability, resulting in feelings of pressure. But a special personal disturbance factor, coming into play injured, despite being considered a debilitating item, appears to be a routine for soccer players. A player's narrative can show this situation: "*I have suffered a sprain in my right ankle in a dispute with opposing defenders ten days ago, but even so I continued to play.*" Conflictive situations like that can interfere with the player's physical/psychic balance and game behavior, contribute to burnout and some kind of "hiding" behavior in practice (Semerci, 2019), and consequently, activity engagement is impaired when there are conflicts (Chan et al., 2019).

Thirdly is a fact inherent to soccer concerns to the ongoing or definitive score of a game. Losing from a special score seems like a difficult time that can decide future performance in games. Being imminent or real failures, these stressful situations during competitions provoke psychological disorders and may negatively affect the athlete's performance (Bailey et al., 2010; Bennett and Maynard, 2017; Brown and Fletcher, 2017). According to Bransen et al. (2019) soccer players are often confronted with in-game situations that could affect their performance, which attest to the need to have a special look at the relationship between certain stressful situations and performance.

However, the most intensely stimulating situations showed that the possibility of success is the motivational key for a soccer athlete. Elite athletes indicate that perceiving success increases their desire to continue practicing the sport, the desire to try harder, and the actual level of effort employed. In this sense, the goal refers to the athlete's ambition to achieve a certain sporting result. His pressure indicates performance expectations, pressure to meet the established goals, and "positive obligation" to win a certain game and achieve expected results. These agree with Scanlan et al.'s (1989) studies and is confirmed by a narrative of a player: *"I am very critical of myself and I always want to play well. After the game, I analyze everything I did and try to get even better."* But it is interesting to note that according to Cohn (1990) and Woodman and Hardy (2001) from a cognitive point of view, the perception of pressure from the player to perform well implies great tension on him to the extent where the demands of the sport can exceed the rewards. Our results show the opposite: self-pressure items were evaluated as positive factors, therefore, a performance facilitator.

Specifically, in our study some stressors from the in-game demands have been linked with positive emotions. Traditionally in soccer it is expected that since a team plays in their own "home," they will already have an advantage in terms of results because they have the support of the fans. Coaches and players believe in the advantage of playing at home (Snyder and Purdy, 1985; Arboix Alió et al., 2020), and about that one player said, *"The pressure of the spectators at home usually influences the performance of the team, which falls in production when is not supported."* Diana et al. (2017) evaluated the game structure in different contexts (home and away) and showed that the game location strongly influences the game tactics. Another stressor, especially for Brazilian players, is related to positive emotion when playing a derby. Certain games are important by their own characteristics. Because of their impact, significant events have special meanings for players, and playing a derby is almost always associated with memorable memories (Brandão, 2000) as it involves situations with great expectation of performance,

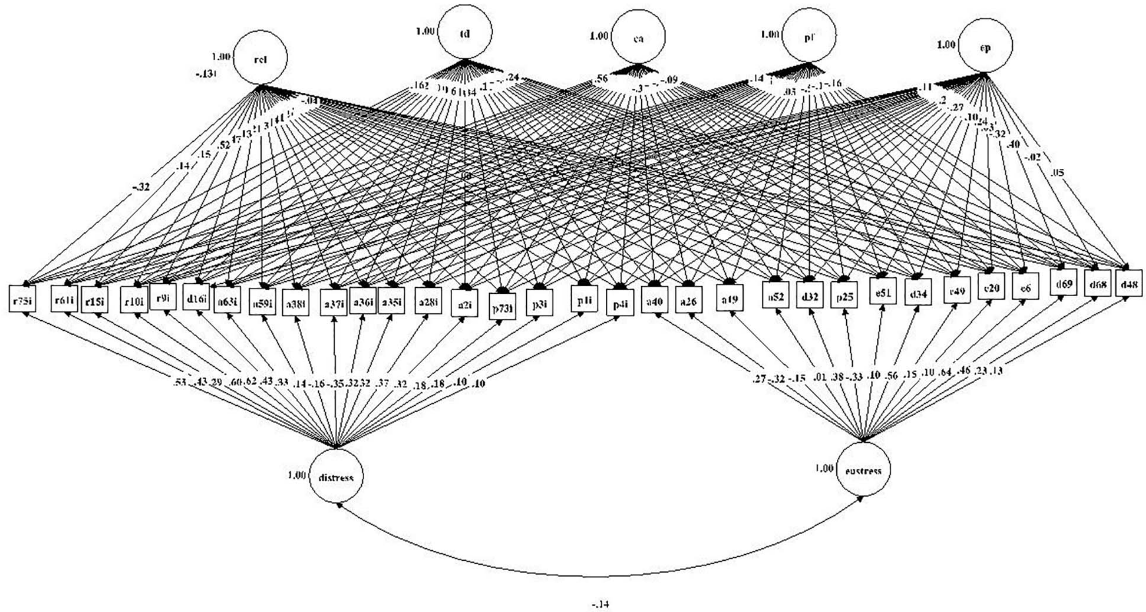

FIGURE 5 | Path diagrams of model. Bifactor solution including global factors (eustress and distress) and specific factors (rel, ac, td, pf, and ep). Note that path diagram figures are only intended to be illustrative as providing detailed labels would make the diagrams too large to present.

experienced as decisive. Beyond that, a "derby" in soccer is a match that mobilizes players, coaches, fans, and the press, even if its result does not interfere with the team's position on the championship. The following assertion illustrates its importance: "*A derby has a shirt, players, mystique and fans.*"

It is well known in the literature that strength, power, and speed make a difference in the physical (and tactical) performance of soccer players. The determinant abilities in a soccer match involve high demands of speed, agility (change of direction without previous knowledge about the local where the change of direction would be done, involving decision making), and change of direction (in this case, the athletes know the exact time and local of the change of direction), as signaled by Polito et al. (2017). Furthermore, in soccer, speed is a physical problem, but it also involves decision making that will lead to movements. Thus, speed can influence the game's outcome (Ekblom, 1995) and it is perceived by the players: *"A player who has great speed, has a fundamental characteristic for the game tactical scheme."*

One aspect that was considered highly positive by the athletes was to know in advance that they are going to be titular. For Lachman (1974) stimulus that is unexpected or suddenly introduced can generate negative emotional reactions. Being warned that they will be a titular minutes before the game require them a quick adaptation and a mental preparation to the new situation according to the demands of unexpected situations: *"The undefinition of the coach about who is going to play often brings a certain emotional instability to the group."* However, some coaches prefer to decide or disclose the squad at the time of the game, which can generate negative feelings and behaviors, as said one player: "*When the player does not know if he will play, he has 2 thoughts, one positive and one negative. He thinks: if I am going to play, I pay attention to the pep talk before the game. But if he thinks: I can stay out, he doesn't even care about the game. So, if he finds out in the locker room that he is going to play, it takes him by surprise.*" According to Brandão (2000), ideally, the player should be informed in advance that he is going to play, so that he can prepare himself and have an appropriate mental tactic for the game. Besides, he should know his opponent's level of performance, physical and mental skills and disabilities, and tactics: "*It is always better to know in advance that you are going to play, you can prepare psychologically better for the game,*" said one of the players.

Apitzsch (1995) stated that the perception of individuals from the external world is not objective but is influenced by subjective interpretations derived from past experiences. According to him, the experience is usually linear with age and with time as professional, meaning that physical, technical, tactical, and psychological skills should increase as a result of increased practice in training and competitions. Younger athletes with little competitive experience do not know the different moments and situations they will face. As a result, they tend to respond to stimuli from the environment differently from more experienced athletes, who have experienced identical or similar situations. Based on this premise, we sought to investigate the differences in the perception of stressful situations according to age and time as a professional, testing the hypothesis that there would be a difference due to these categorical variables. Older and more experienced athletes were expected to perceive situations as less negative to sports performance.

Our results first confirmed the hypothesis and are in accordance with studies conducted by Mahoney et al. (1987) who observed that the most experienced athletes had better concentration before and during competitions, were more self-confident, had a high capacity to recover from errors, experienced less stress before and during competitions, and interpreted anxiety as a facilitator unlike the less experienced (*"This is my first derby against Palmeiras as a professional. I was sleepless in the face of such a responsibility"*), who tended to interpret anxiety as more debilitating to performance (*"Some players lost their emotional balance at the wrong time. Lack tranquility, calm, it's a very young team"*). Gould and Krane (1992) showed that experienced athletes have different standards when compared to less experienced athletes in terms of stress reactions; Régnier et al. (1993) studied those who have a systematic difference in how increasingly experienced athletes perceive and respond to different environmental stimuli; Brandão (2000), when assessing more experienced soccer players, noted that they evaluated competition situations as less unfavorable to performance than players with less experience. Evidence suggests that, based on previous experiences, more experienced athletes subjectively estimate the probabilities of events and react to them less negatively ("*Insecurity only gets hold of the athlete when he doesn't have enough experience to believe that he knows how to play*"). The knowledge of the probability of the different events in the sports environment is for Abernethy (1993) a great advantage for the most experienced athletes.

Identifying the antecedents of stress in sport has been an important area of investigation for both theoretical and practical reasons (Ruiz et al., 2019). Familiarity with the categories of stress that are supposed to influence athletes' emotions and can trigger negative or positive responses will clarify the concept of stress and identify which situations potentially depress performance and which one facilitates performance. Still, it will also help in planning the regime of physical, technical, and tactical training and the preparation of players for the competitive process. Furthermore, when stress categories are chronic negative this can result in "burnout," lack of motivation, poor sports performance, and even abandonment of competitive sport (Anshel, 1990). A special aspect to be addressed at this point is how the perception of stressful situations also can be different depending on the player's culture, as analyzed by Brandão et al. (2013). This perception opens an avenue of interesting studies for colleagues from other countries who want to assess the perception of stress in their players and compare it with the Brazilian players.

Related to the List of Stressors in Soccer's factor-structure, although the model had satisfactory adjustment rates, not all items loaded the respective S-factor or G-factor as strongly as expected. Some of the estimated factor loads for this model proved to be insignificant, which is consistent with the nature of the two-factorial models, in which each item cannot realistically be assumed to have equally strong associations with global and specific factors (Morin et al., 2016). Specific patterns of significant versus non-significant loads may help us to interpret specific items and those that should be classified as stress and/or distress. Future research should look for ways to refine the items designed to improve stress assessment and test them on a large sample to increase this list's significance.

In conclusion, the results revealed that Brazilian professional soccer players in this study experience various stressful situations. These events are important representations of environmental demands and could predict the performance as they are perceived as distress or eustress. Some of these stressful situations are inherent to the sport environment, and others are adjacent to the sports system or environment. Coach pressure to win and conflicts with teammates are examples of stressors within the team. Family problems and conflicts with press or fans are examples of stressors external to the team, also called peripheral opponents, and showed the relative social influence of significant others in soccer performance.

It is important to highlight that the *List of Stressors in Professional Indoor and Field Brazilian Soccer* was elaborated to fit a specific sport, soccer, indoor and field, and use it to observe the debilitating or facilitating character of stress factors. Knowing the directionality of a given stress factor has important practical implications in preparing athletes and helping them face the performance stressors that are part of the daily life of soccer. This knowledge can also help future athletes and coaches minimize the factors considered negative, which play a critical role in the appearance of psychological and psychosocial disorders and strengthen the positive ones, which significantly impact the players' motivation.

In this sense, it is believed that the perception of stressful situations and the intensity they affect players behavior should be examined as the players' set of psychosocial situations; individual experiences in terms of training, team's social relationships, contract negotiations, player transfers, in addition to competitive and non-competitive aspects and the team's physical, social, and cultural factors in which the player plays, their infrastructure, media attention, and player support. Furthermore, in a broader sense, in the historical and contemporary contexts in which the athletes are involved, they cannot be satisfied only with this knowledge, but rather convert it into practical training for stress control.

An important delimitation for this study is the following: the small number of futsal players in relation to soccer players, due to the pandemic, so it was not possible to test the hypothesis that there would be no difference in the perception of stress due to this categorical variable.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Comitê de ética em pesquisa Universidade São Judas Tadeu. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MRFB and LFP conceived the original idea of the study. VH, MC, APM, DO, AO, and LM selected the researches and contributed to data processing and analysis. DA analyzed and presented the data. MRFB, DA, and MVBJ wrote and organized the manuscript. All authors reviewed the manuscript and approved the final version for submission.

ACKNOWLEDGMENTS

Special thanks to all teams and players that made possible this research.

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 28 May 2021
doi: 10.3389/fpsyg.2021.661262

Monitoring and Behavior of Biomotor Skills in Futsal Athletes During a Season

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Specialty section:
This article was submitted to Movement Science and Sport Psychology,
a section of the journal Frontiers in Psychology

Received: *30 January 2021*
Accepted: *28 April 2021*
Published: *28 May 2021*

Citation:
Stochi de Oliveira R and Borin JP (2021) Monitoring and Behavior of Biomotor Skills in Futsal Athletes During a Season. Front. Psychol. 12:661262. doi: 10.3389/fpsyg.2021.661262

Futsal is a sport that presents alternation of high and low intensity moments, which lacks investigations regarding the effects of the organization of the training load on biomotor skills. In this sense, this study aims to verify the monitoring of the training load throughout the season and the behavior of biomotor skills in futsal athletes. Twelve futsal athletes (24.5 ± 4.9 years, 1.79 ± 0.6 m, 72.4 ± 9.4 kg, and 9.4 ± 4.3% fat) from the adult category who competed in the first division of the Paulista championship participated in the study. Throughout the season the internal training load (ITL) was calculated, through the relationship between volume (minutes) and the rate of perceived exertion (RPE), monotony, and training strain. The training periods were divided into: preparatory, competitive and competitive II, for a total of four moments of evaluation: M1: at the beginning of the preparatory period; M2: 5th week, at the end of the preparatory period; M3: 13th week, in the middle of the competitive period; and M4: at the start of the competitive period II. The tests used were: (i) Power of lower limbs: counter movement jump (CMJ); (ii) Displacement speed, over the 10-meter distance (V10m); and (iii) Aerobic power, by the Carminatti test (T-CAR). The variables analyzed were compared at the different moments of evaluation, normally distributed variables (Volume, S-RPE, strain, and monotony) were analyzed using the ANOVA ONE-WAY variance test followed by the Tukey. Variables that did not show normality (lower limb power, speed, and aerobic power) were compared using the Friedman test followed by Dunn's multiple comparisons test and was presented by median and interquartile interval. The significance value adopted was $p < 0.05$. A significant improvement ($p < 0.05$) was observed in the power of lower limbs from M1 (37.5 ± 5.5 cm) to M3 (40.8 ± 5.7 cm), from M2 (38.9 ± 5.5 cm) to M3 (40.8 ± 5.7 cm), and from M1 (37.5 ± 5.5 cm) to M4 (40.2 ± 5.4 cm). Aerobic power showed a significant increase ($p < 0.05$) from M1 (12.1 ± 0.7 km/h) to M3 (12.7 ± 7 km/h) and from M1 (12.1 ± 0.7 km/h) to M4 (12.73 ± 1.04 km/h). The internal training load showed a difference between competitive I and II in relation to the preparatory period ($p < 0.05$). In conclusion, the proposed training organization was sufficient to improve the power of the lower limbs and the aerobic power.

Keywords: training load, futsal, monitoring, physical performance, training

INTRODUCTION

Futsal started in the 1930s in South America as an indoor version of football and has since expanded rapidly around the world. Currently, the sport has its rules governed by FIFA and is practiced by more than 130 countries. The world cup takes place every 4 years, and since 2012, 24 teams have taken part in the competition. In recent years, numerous changes regarding the rules have been made, making the sport more dynamic and intense (Matzenbacher et al., 2014).

The popularity of the sport has fostered research in different domains: physical (Barbero-Alvarez et al., 2008, 2015; Alvarez et al., 2009; Castagna et al., 2009; Milanez et al., 2011; De Oliveira Bueno et al., 2014; Naser et al., 2017; Ayarra et al., 2018; Yiannaki et al., 2020), physiological (Barbero-Alvarez et al., 2008; Oliveira et al., 2013; Arruda et al., 2015; Wilke et al., 2016; Padoin et al., 2020), and control of the training load (Miloski et al., 2014, 2016; Beato et al., 2017; Clemente et al., 2019).

Those previously cited bodies of research characterized futsal as an intermittent modality, alternating high-intensity efforts with short periods of recovery, requiring energy supply both from the aerobic pathway considered predominant during the match and from the anaerobic pathway, the latter being determinant, since actions such as sprints, changes of direction, accelerations, and decelerations can be decisive for the success in the match (Beato et al., 2016). In a study by Ribeiro et al. (2020), it is shown that one of the important loads imposed on athletes is the deceleration that happens during changes in direction and technical and tactical actions. This finding corroborates the studies on the development and improvement of neuromuscular abilities for optimal performance in futsal matches that were mentioned above.

Based on the characteristics of the actions of the sport, there is a pattern in the prescription of training means and methods, both directed to tasks that develop endurance capabilities as well as to the training of the neuromuscular capabilities of athletes to obtain a better competitive performance; however, this seems to be a challenge for coaches and physical trainers due to the concurrent effect that exists in futsal (Nakamura et al., 2016a). An effective strategy to overcome this problem and understand the dynamics of the training load distribution, is focusing on monitoring the training load imposed on the athlete. In team sports, the training load ca be divided into external training load which is the training prescribed and, internal training load which is the training effect (Issurin, 2019).

The ultimate goal of training is to obtain positive adaptations through appropriate training loads. For this to occur, it is necessary to correctly manipulate training variables such as volume and intensity, as well as offering adequate recovery periods. A path to monitoring the training load is and session-RPE designed by Foster (1998). In team sports, especially in futsal, s-RPE is widely used because of its applicability, ratability and internal consistency (Haddad et al., 2017). The session-RPE method takes into consideration the duration of the training session, expressed in minutes and the intensity is given by an athlete through the RPE scoring the intensity of the training session. Thus, the training load is the product of the volume and intensity.

Classical studies on futsal investigated training load. Miloski et al. (2012), who sought to understand the quantification of internal and external load in a 14-week futsal season, presented training parameters. For instance, the ITL was quantified using the S-RPE method (Foster, 1998) and found that the ITL was higher during preseason than during the competitive period, but they also recognized one limitation of the study, which was the need for further investigation into the performance of athletes along with the preparatory and competitive periods. Another study led by Oliveira et al. (2013) shows interesting results regarding physical changes during a training macrocycle (preseason and season) and changes in heart rate variability. Miloski et al. (2016) quantified the ITL, using S-RPE, during 22 weeks in a futsal team. The authors classified the ITL in four different zones, such as being ITL $\leq$ 25% (of maximum): low loads; 25–50%: moderate-low loads; 50–75%: moderate-high loads; and $\geq$75%: high loads; however, no data were investigated regarding the distribution of volume and intensity, as well as the relationship with training organizations and biomotor capabilities.

Other studies aimed to investigate the organization of training and its response either on physical performance or results in a competition. For instance, Thiengo et al. (2013) investigated the organization of training loads on biomotor capabilities quantifying the volume of training in 5 weeks of the preparatory period for amateur futsal players. As a result, the authors found that 1,530 min of training is subdivided into 40% of metabolic and technical/tactical training, and 60% on neuromuscular training, such as strength, power, and speed. In response to this form of organization, the athletes achieved 13% of improvement in maximum anaerobic power and 4.4% of improvement in the power of lower limbs. Cetolin and Foza (2010) studied under-20 futsal players for 4 months and monitored the athletes' external load during the whole season. For the first month, the training emphasis was based on specific endurance and aerobic power; for the second month, the activities focused on strength and speed; lastly, in the third and fourth months, speed training was increased. As a result, the team won more than 70% of the matches during the competition.

Rocha et al. (2015) studied the changes in performance and biochemical indicators of a team. In addition, Teixeira et al. (2018) monitored and compared the quantification of the training load in two futsal teams and observed the metabolic and neuromuscular responses; however, that investigation, although necessary, occurred only in the first 5 weeks that characterized the preparatory period. Lago-Fuentes et al. (2020) described both external training load and ITL in a professional female futsal team during 43 weeks and compared workloads during different periods of the season. The authors found interesting results relating to the pattern of workload organization throughout the season. Wilke et al. (2021) compared the post-training recovery timeline of elite Brazilian futsal players during 10 weeks of preseason. In summary, they found that the organization of training attenuated the perception of effort and fatigue of players, therefore improving the recovery of power, muscle damage, and vigor markers.

To the best of our knowledge, most studies regarding futsal are specific to one period of the season, investigating hormonal responses, quantifying the intensity of training, and evaluating the changes in performance. Albeit interesting, it appears to be a limiting factor. From the aforementioned research, few studies investigated the entire training season, and none quantified the relationship between volume and intensity in biomotor capabilities responses. For instance, all the studies investigated the training load proposed by Foster (1998), but none of them indicated whether the training load was greater because of the training volume or intensity at different periods of the season. Given the above, there is a hypothesis that either the volume or intensity of training may affect the total training load. Furthermore, the dynamics of these variables can cause positive or negative effects on athletes' body.

Thus, the present investigation is justified for it contemplates research within a complete season, encompassing both preparatory and competitive periods. The objective, therefore, is to verify the monitoring of the training effect and to compare the responses of biomotor skills at different times of the competitive season.

MATERIALS AND METHODS

Participants

Twelve futsal athletes who competed in the first division of the Paulista Championship participated in this study (24.5 ± 4.9 years, 1.7 ± 0.6 m, 72.4 ± 9.4 kg, and 9.4 ± 4.3% fat). All the athletes had at least 5 years of experience in the sport, having played in the national and international championships. Participants were informed about the study by the responsible researcher and subsequently signed the informed consent form that was previously approved by the Research Ethics Committee of the State University of Campinas, under CAAE no. 48065615.0.0000.5404.

Design and Procedures

The training macrocycle consisted of 20 weeks, 5 in the preparatory period, 11 in the competitive period I (qualifying phase), which featured 12 official games, and 4 weeks of competitive period II (play-offs). **Figure 1** illustrates the experimental design of the study along with the moments of the evaluations (M). Tests were carried out in order to assess aerobic power, power of lower limbs, and speed. To avoid any kind of influence on the results and as a form of standardization, athletes performed a battery of tests with, at least, 48 h of rest. The speed and power tests of the lower limbs were performed in the morning between 9:00 a.m. and 12:00 p.m., and the aerobic power test was performed in the afternoon between 3:00 p.m. and 5:00 p.m. The athletes wore their own training clothes, such as t-shirts, shorts, socks, and indoor soccer shoes. The tests were applied by the responsible researcher and the technical staff.

Training Program

The training schedules during the season were planned entirely by the coaching staff of the team without intervention by the authors of this study. The team aimed to develop technical tactical skills, strength-power training, aerobic power, and, finally, matches (**Table 1**). The athletes trained once or twice a week, depending on the schedule of the coaching staff of the team. The training week consisted of 7 days containing a minimum of 7 training sessions and a maximum of 11 training sessions. The preparatory period had a range of 9–11 sessions per week, and competitive I and II had a range of 7–9 sessions per week. Each session lasted an average of 90 min. After each training session, one of the authors of the study gathered with the technical staff to compute the training sessions and then quantify according to the classification in **Table 1**.

Monitoring of External Load

The strength and conditioning coach of the team along with one of the authors recorded day-to-day training in digital diaries designed by technical staff (Excel spreadsheet). The training was recorded for each session and included total training time distributed across training form (endurance, specific endurance, strength, power, technical/tactical drills, and matches). In each week, the total weekly external training load was calculated by adding the training minutes, and the total external load (training time) of each period was estimated as the mean of the total weekly training load.

Monitoring of Internal Load

To calculate the training load according to the procedures described by Foster et al. (2001), the training time (in minutes) of each session was measured, as well as the intensity, through the S-RPE reported by the athletes. The scale is graded from 0 to 10 points, with the value 0 (zero) representing no effort and 10 (ten) representing the maximum perceived effort. S-RPE was recorded 30 min after each training session, after the reported RPE score was multiplied by total session duration, in minutes, to indicate the training load. In each week, consisting of 7 days, the total weekly training load was calculated by adding the training loads of the session. The total ITL of each period was estimated as the mean of the total weekly training load. During the competitive phase, the RPE of the match was also recorded. The time that each athlete was on the court was added and multiplied by the reported RPE value. The monotony and strain were also calculated. Monotony indicates the load variability between training sessions and was obtained by the ratio between the mean and the SD of the internal load. The strain is associated with high monotony and might indicate overtraining and was obtained by multiplying the total training load by monotony. The mean of the total training load, strain, monotony, RPE, and training volume was calculated for better visualization of the external and internal loads (Foster, 1998; Foster et al., 2001).

Testing Protocol

Power of Lower Limbs

To evaluate the power of the lower limbs, the vertical jump test with the countermovement jump technique (CMJ) was used

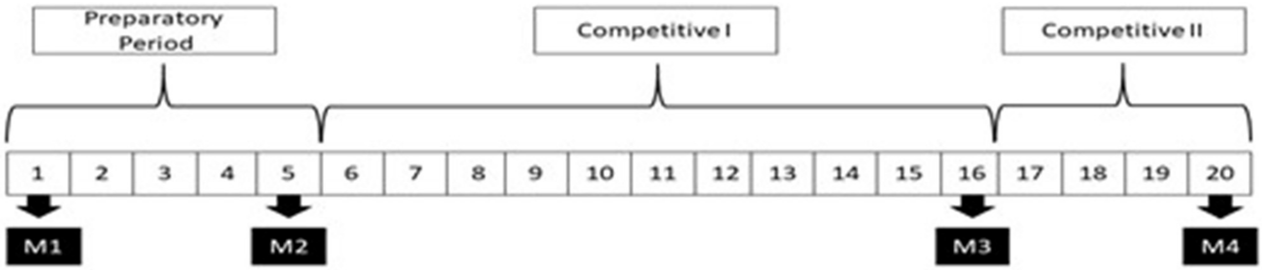

FIGURE 1 | Periods of training and assessment.

TABLE 1 | Training content.

Training	Content
Technical–tactical	• Transition games (attack–defense, defense–attack) with and without a numerical difference; simulated games training
Strength–power	• Strength training for lower and upper limbs: 3 to 4 sets of 8 to 15 maximum repetitions, with 2 min of recovery between sets and 3 min between exercises • Strength training for lower and upper limbs: 3 to 5 sets of 2 to 5 maximum repetitions, with 3 to 4 min of recovery between sets and 5 min between exercises • Resisted runs 10 to 15 m • Vertical jumps with heights of 20 to 70 cm, horizontal jumps and unilateral jumps • Plyometric training using different drop heights (20, 40, and 60 cm).
Endurance and specific endurance training	• Extensive interval runs with stimuli of 8 to 10 min at threshold speed with intervals of 3 min of recovery • Intensive interval runs, with 4-min stimuli at 90% of maximum heart rate, and with 3-min recovery at 70% of maximum heart rate • Small sided games (1 × 1, 2 × 2, 3 × 3, 4 × 4)
Matches	• Training games and official matches

according to the protocol proposed by Bosco et al. (1983). Each athlete made three attempts with a 10-s interval, the highest value among them was used. To perform the test, a CEFISE® contact mat connected to a portable computer was used, and from the time of flight, the height of the jump was calculated using specific software.

Displacement Speed

The protocol proposed by Little and Williams (2005) was used to evaluate the displacement speed over 10 m. The athlete positioned himself, standing in the starting line, and at the command of the evaluator, ran at maximum effort in order to cover the stipulated distance in the shortest possible time. Three attempts were made, with an interval of 2 min between them, the best of which was computed. Two CEFISE® photocells were used for the evaluation of the displacement speed, being placed at the start and end points of the test.

Aerobic Power

To measure the aerobic power of the athletes, the incremental intermittent running test, T-Car, (Da Silva et al., 2011) was used. The test consisted of 90-s stages. In each stage, 5 repetitions of 12 s of running were performed (6 s "to go" and 6 s "to come back") interpolated with 6 s of recovery. The pace was dictated by an audio signal (beep), with regular intervals of 6 s that determine the running speed in the displacements predicted in each stage.

Statistical Analysis

The data obtained were tabulated and analyzed using GraphPad Prism 8.0 for Windows. After analyzing the data distribution using the Shapiro–Wilke test, normally distributed variables (volume, S-RPE, strain, and monotony) were analyzed using the one-way ANOVA test followed by Tukey's range test. Variables that did not show normality (lower limb power, speed, and aerobic power) were compared using the Friedman test followed by Dunn's multiple comparisons test and were presented by the median and interquartile interval. The magnitude of effect for pairwise comparisons was analyzed using Cohen's d with a 95% confidence interval. The magnitude of d was qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; and 2.0 to 4.0, very large (Cohen, 1994).

RESULTS

The results are presented below by training periods at mean values and SD. **Figure 2** points to the distribution of the total ITL (A), the volume (B), and the RPE of the session (C). Regarding volume, the preparatory period was higher by 539.0 (30.2) min than other periods ($p < 0.01$), with no significant differences between competitive period I 435.9 (42.8) and II 453.8 (58.5). The S-RPE presented higher values ($p < 0.03$) between competitive I 6.7 (0.61) a.u. and II 6.8 (0.50) in relation to the preparatory period 5.3 (0.5) a.u.. **Figure 3** shows monotony and strain, in which the monotony shows a significant difference ($p < 0.01$), revealing that the preparatory 1.7 (0.15) a.u. and competitive II 1.7 (0.06) a.u. periods presented higher values than competitive I 1.4 (0.8) a.u. The strain showed no difference between the periods.

Figure 4 and **Table 2** present the results of the biomotor capabilities (CMJ, Speed, T-CAR). CMJ improved from M1 [37.5

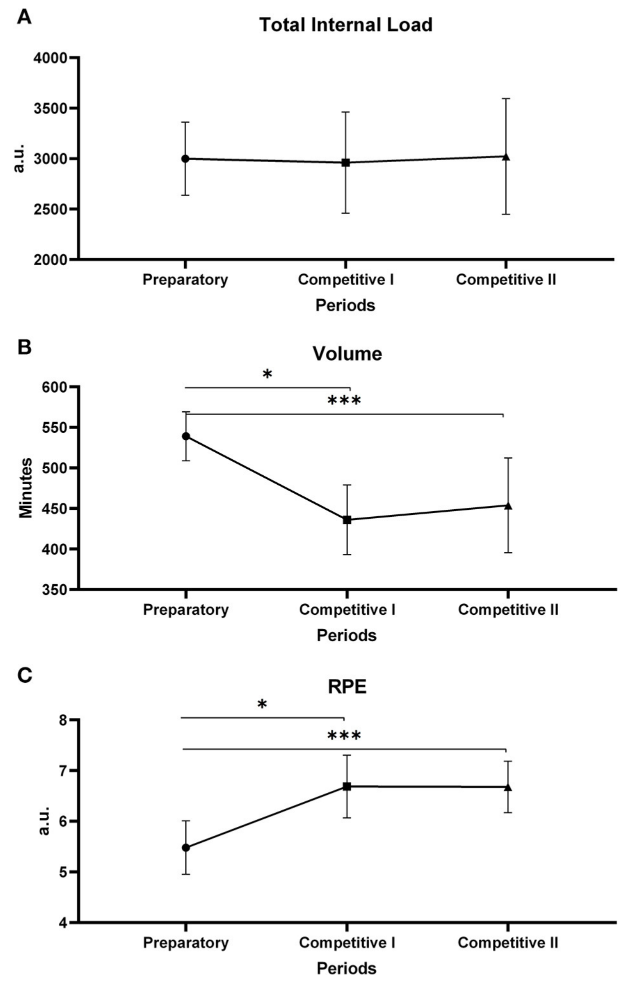

FIGURE 2 | (A) The total internal training load between periods. **(B)** Training volume between periods. **(C)** S-RPE between periods. *Difference between preparatory period and competitive period I, ***Difference between preparatory period and competitive period I.

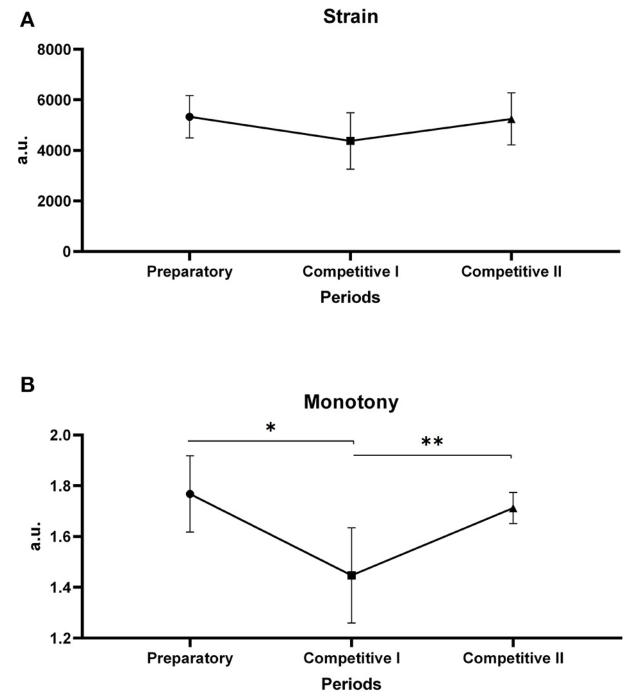

FIGURE 3 | (A) The strain between periods. **(B)** Monotony between periods. *Difference between preparatory period and competitive period I, **Difference between competitive period and competitive period II.

(5.5) cm] to M4 [40.2 (5.4) cm] and from M1 [37.5 (5.5) cm] to M3 [40.8 (5.7) cm ($P < 0.05$)]. T-CAR shows a significant difference ($p < 0.05$) between M1 [12.1 (0.7) km/h] and M2 [12.8 (0.6) km/h], between M1 [12.1 (0.7) km/h] and M3 [12.9 (0.7) km/h], and lastly between M1 [12.1 (0.7) km/h] and M4 [12.7 (1.0) km/h]. Speed tests presented moderate changes between M1 and M3 (d = 0.68; moderate). **Figure 5** shows the time allocated for different training content, in percentage values. It is immediately possible to observe throughout the macrocycle the predominance of technical–tactical training, except in weeks 1 and 2.

DISCUSSION

The discussion of the data is presented by training periods, so that the preparatory period will be discussed first, followed by competitive periods I and II. The present study sought to verify the monitoring of the training effect and to compare the responses of biomotor capabilities at different times of the competitive season. This study was motivated by the need to understand the organizational structuring of the training load, especially in futsal, since this modality is in the spotlight worldwide and its competitive calendar has a large number of matches. From the data obtained, it is possible to observe that the training organization presented in the study did not show a significant difference in the total training load during the periods analyzed; however, when checking the other variables related to training load, the volume of training was higher in the preparatory period, and the intensity, represented by the S-RPE of the session, was higher in the competitive periods. During the competitive period II, the highest values were found both in the CMJ and in the aerobic power tests, and the lowest monotony values were found in the competitive period I.

It is noted that the training periods are well-defined, even though they have presented different numbers of microcycles between them. As for the preparatory period, it was found that the total ITL does not agree with previous studies that investigated high-level futsal players, such as that of Miloski et al. (2012), and reported higher values of total internal load in the preparatory period. The same pattern of training load distribution was found in another study by Miloski et al. (2016), yet none of them identified which of the variables influenced the training load. In the present study, the volume was predominant in the preparatory period. Such values correspond to the study by Thiengo et al. (2013), where they found high scores in the

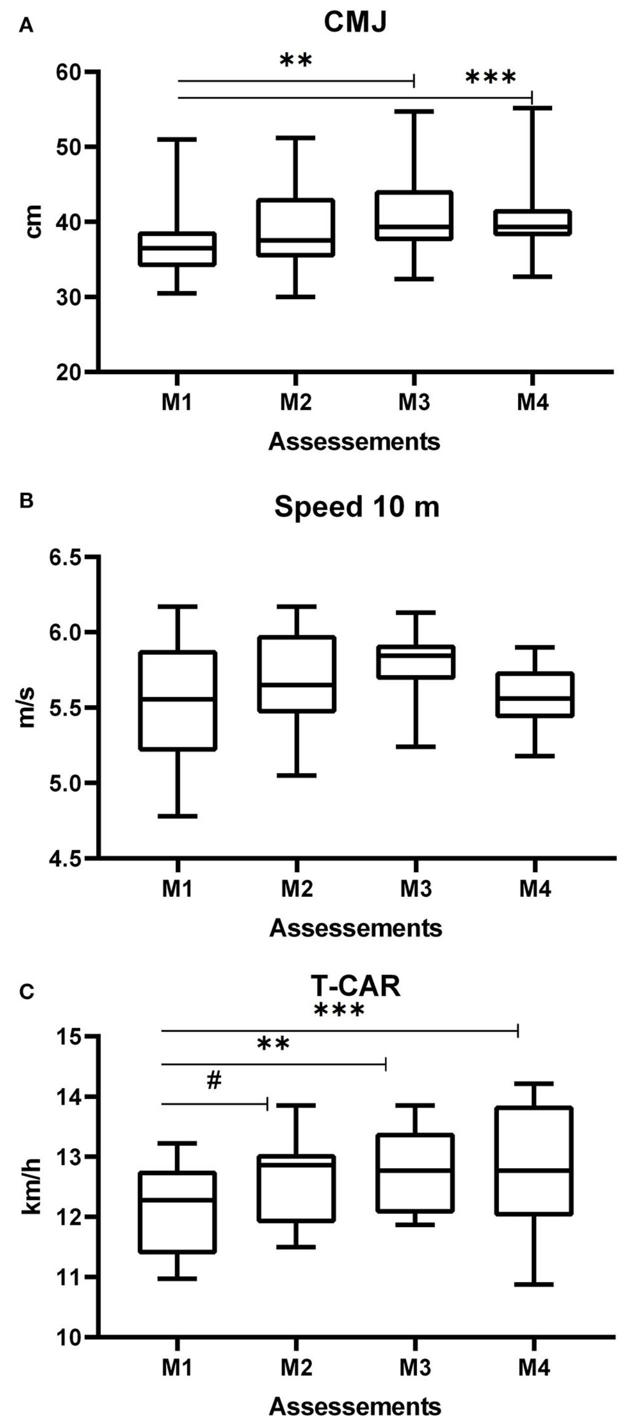

FIGURE 4 | (A) CMJ. **(B)** Speed 10 meters. **(C)** T-CAR. #Difference between M1 and M2, **Difference between M1 and M3, ***Difference between M1 and M4.

volume of training in the 5 weeks of the preparatory period in a professional futsal team. Lago-Fuentes et al. (2020) also observed high volumes at the beginning of the season. In fact, these high numbers in the preseason can be explained by the need to develop and improve neuromuscular and metabolic capabilities and tactical technical training.

When looking at **Figure 5**, it can be seen that, in the first 5 weeks, most of the time was devoted to technical and tactical training, though the strength, power, and endurance capabilities were also developed during this period. This volume distribution made the intensity represented by S-RPE lower in the preparatory period. Moreira et al. (2013) quantified the training intensity in three zones based on the session RPE (low, <4; moderate, >4 au and <7 au; and high, >7 au). Regarding the values mentioned above, we can assume that the S-RPE was considered moderate during the preparatory period. These data are similar to previous studies which were found values between 5 and 6 points on the mean RPE (Teixeira et al., 2018; Lago-Fuentes et al., 2020). So, the present study showed a preparatory period with high volume and moderate intensity. These behaviors can be explained by the number of training sessions during the preparatory period and also by the short time that tam sports, especially futsal, have designated for practices before a competition (Miloski et al., 2012), considering that if both high volume and high intensity were prescribed within the same period, the training load could rise to undesirable levels, causing negative adaptations to the body of the athlete.

It was pointed out by Fessi et al. (2016) that excessive high-intensity training in the preseason is generally associated with greater monotony, strain, fatigue, and muscle pain than during the in-season. Of the indicators mentioned above, monotony was below 2 a.u. (arbitrary units) in the preparatory period. According to Foster (1998) and Suzuki et al. (2006), values above 2 a.u. indicate little variability of the load, causing no adaptation to the training process. Strain is also associated with the level of adaptation to training, in which periods with a high load associated with high monotony can increase the incidence of infectious diseases and injuries. In the present study, the values did not exceed 5,000 a.u., unlike the study of Miloski et al. (2012) with futsal athletes, in which scores lower than those in this study were found at 37 weeks 2,270 ± 1,294 (213 a.u. a 4,771 a.u.). Despite the greater results presented in the study, the values are still within acceptable standards, since according to Foster (1998), values of strain close to or >6,000 a.u. favor the development of diseases and negative adaptations to the body of the athlete.

The organization of the training variables and the response of strain and monotony indicators are reflected in the adaptation to training by the athlete. Such adaptation can be observed in the behavior of biomotor capabilities in the preparatory period. It is worth noting that the evaluations carried out between M1 and M2 coincide with this period and suggest that the preseason did not provide sufficient stimuli for significant gains in neuromuscular capabilities. This can be attributed to the concurrent effect caused by large volumes of training aimed at functional capabilities, such as aerobic resistance and tactical technical training (Loturco et al., 2015). Previous investigations with futsal athletes, such as Soares-Caldeira et al. (2014), found no changes in lower limb power in 4 weeks of preseason. Likewise, Miloski et al. (2016) who investigated 22 weeks of training found no changes in the power of lower limbs in

TABLE 2 | Effect size and descriptive measures of biomotor capabilities at different times using Cohen's d with 95% confidence interval.

Descriptive measures		M1	M2	M3	M4	Effect size	M1-M2	M1-M3	M1-M4	M2-M3	M2-M4	M3-M4
CMJ	Mean	37.5	38.9	40.8*	40.2**	ES	0.26	0.59	0.51	0.34	0.25	0.58
cm	SD	5.5	5.5	5.7	5.4	Cohen	Small	Moderate	Moderate	Small	Small	Moderate
Speed 10 m	Mean	5.5	5.6	5.7	5.5	ES	0.4	0.67	0.13	0.26	0.43	0.83
m/s	SD	0.4	0.3	0.2	0.2	Cohen	Small	Moderate	Small	Small	Moderate	Large
T-Car	Mean	12.1	12.6#	12.7*	12.7**	ES	0.63	0.71	0.66	0.12	0.13	0.02
Km/h	SD	0.7	0.7	0.8	1	Cohen	Moderate	Moderate	Moderate	Small	Small	Small

The magnitude of d was qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large and 2.0 to 4.0, very large.
 # Difference between M1 and M2.
** Difference between M1 and M3.*
*** Difference between M1 and M4.*

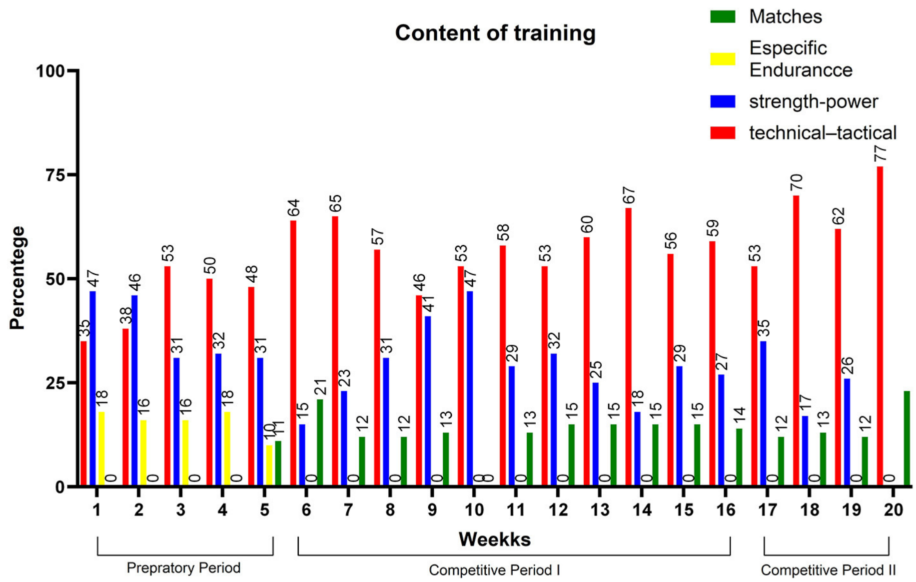

FIGURE 5 | Relative training volume.

the 6 weeks intended for preparation. The authors attribute this result to the difficulty of promoting the distribution of training in order to develop multiple components (physical, technical, and tactical) during short periods of preparation. Nonetheless, the effect size of the neuromuscular capabilities shows a small effect, while the resistance capability shows a moderate effect improvement.

Although there was no improvement in performance during the preseason due to the short period of time, the fatigue perception and recovery from session to session may have improved. Wilke et al. (2021) compared the post-training recovery timeline of elite Brazilian futsal athletes before and after 10 weeks of the preseason. They presented similar results with this study, showing no improvement regarding CMJ, speed, and endurance capacity. The authors observed that players perceived the session as less intense, which supports the notion that exposure to training may improve the perception of the load and, in turn, perhaps the tolerance to fatigue. Therefore, it was presumed that the ratio between tactical, neuromuscular, and metabolic technical training in the preparatory period triggered positive adaptations in the bodies of athletes, since there was no loss of performance. The time allocated for preseason, however, was too short for significant improvements. Freitas et al. (2012) pointed out that for high-performance futsal, the preparatory period is short and it aims to establish the sport-specific physical preparedness, so that, later on, it can be maintained in the best possible way during the competitive period.

When analyzing the competitive period that consists of the competitive periods I and II, it was clear that the competitive period I was the one with the longest duration and it represented an important part of the competition which was the classificatory stage. In this period, the total training load did not change in relation to the preparatory period; however, it was observed that the training volume decreased significantly from the preparatory period to competitive I, and the S-RPE increased (**Figures 2B,C**). The mean RPE in our study was 6.7 (0.61) over the competitive period I. These data are higher than previous studies in a season with youth male players (Rabelo et al., 2016), professional male team (Freitas et al., 2014; Miloski et al., 2014), and professional female team (Lago-Fuentes et al., 2020). These dynamics between volume and intensity, on the other hand, is in agreement with the premises found in the classic literature on sports training, which shows that in the preparatory period the training volume is prioritized over the intensity, and in the competitive period there is an inversion, prioritizing the intensity over the volume training (Matveev, 1991, 1997; Forteza de la Rosa, 2006; Gomes and Souza, 2008; Platonov, 2008; Tønnessen et al., 2015).

In addition to the behavior of the volume and intensity variables, the low monotony values in the competitive period I also stand out (**Figure 3B**). As mentioned above, monotony is a potent indicator of the dynamics of training load prescription, as the adaptation induced by training depends on a few aspects, including the stress-recovery relationship (Borges et al., 2019). Foster (1998) and Suzuki et al. (2006) presented evidence that the good performance of sportspeople, regardless of the sport, is related to low monotony values. In fact, it was observed that the players in the present study were subjected to high intensities in the competitive period I, but with low monotony scores. Iaia and Bangsbo (2010) and Laursen (2010), and Mujika (2010) pointed out that prescribing high training intensities with the correct recovery dose favors positive adaptations in the bodies of the athletes, consequently improving the performance of biomotor capabilities. This premise is reinforced by Teixeira et al. (2018) who analyzed two futsal teams subjected to different training intensities in order to observe changes in physical capabilities and concluded that coaches are advised to oscillate the dynamics of the training load applied between the microcycles and allow for recovery cycles.

When looking at the biomotor capabilities, therefore, it is possible to state that these low monotony values may have caused improvements in the height of the CMJ and, consequently, in the lower limb power levels, mainly from M1 to M3. It is worth mentioning that, in addition to the monotony, the proportion of distribution of neuromuscular training and tactical technical training within this period provided positive adaptations in lower limb power gains. For instance, the present study showed a range of strength training between 15 and 47% (**Figure 5**) of total training during the competitive period I. These values are higher than that shown in the study of Miloski et al. (2016), which is in the range between 9 and 22.8%, that is dedicated to strength training during a season in professional futsal players. Loturco et al. (2015) observed the little time being devoted to neuromuscular training, which ended up influencing lower limb power gains in soccer players. It is important to highlight that the increase and/or maintenance of power levels is essential for decisive actions in futsal, especially in actions that require changes in direction, acceleration, and deceleration (Ribeiro et al., 2020).

The displacement speed did not improve between the evaluated moments; however, between M1 and M3, the effect size was moderate, indicating a possible positive change in this capability. One reason for this was the distance used, not allowing for changes in the values found. A study by Oliveira et al. (2019) found improvements in the displacement speed in futsal athletes during 18 weeks of training. Another possibility, and perhaps the most plausible, suggests that the result can be partially attributed to the effects of simultaneous training caused by high volumes of both technical–tactical and aerobic training in the preseason and competitive periods. Previous studies (Loturco et al., 2015) with soccer players did not report an increase in neuromuscular capabilities with short preparation periods (4 weeks), and Soares-Caldeira et al. (2014), with futsal players, point to similar results for speed with short-term preparation period. The distribution of training content in the present study may have hindered the speed during the season. It is possible to observe that, from the 13th week forward, the volume destined for neuromuscular capabilities decreased while it increased for technical training.

Regarding aerobic power, there was a significant improvement in the threshold speeds from M1 to and M3 and, mainly, from M1 to M4. Since futsal is a high-intensity intermittent sport with a predominance of aerobic metabolism (Barbero-Alvarez et al., 2008; Castagna et al., 2009), the volume assigned for technical and tactical training, in addition to solving this task, contributed to the improvement and maintenance of aerobic power throughout the season. In the values found in the present study, more than 50% of technical/tactical training are similar to values found by Freitas et al. (2012) and Teixeira et al. (2018). More time allocated to this kind of training can lead the bodies of athletes toward metabolic adaptation. For instance, Wilke et al. (2016) investigated the metabolic demands of technical and tactical training sessions in professional futsal athletes and showed that the athletes exercised at intensities above the respiratory compensation point in 20.4 (11.78)%, between respiratory compensation point and the ventilatory threshold (VT) in 28.2 (5.6)%, and below the ventilatory threshold in 51.4 (9.7)% of the time during training. Based on the data mentioned above, it was observed in the present study that the technical/tactical training sessions may have been intense enough to cause si'sgnificant changes.

In the competitive period II, the load behavior was similar to the CPI, with an increase in monotony values and in the time allocated for technical and tactical training (**Figures 4**, **5**), which may have reflected in the neuromuscular indicators, especially the displacement speed. Teixeira et al. (2018) also observed loss in neuromuscular indicators in futsal athletes, especially in the displacement speed, being attributed to the accumulation of training load without due time for recovery and to the volume of technical–tactical training, especially for faster players, given that in another study (Nakamura et al., 2016b) it was observed that fast players perceive greater training loads and present greater reductions in displacement speed during periods of high training loads. It is possible to notice that the highest volumes of technical–tactical training took place from week 17 to week 20, which agrees with the findings of the studies cited above, showing there was a possible interference of the volume of technical–tactical training along with the increase in monotony on the possible decrease in speed.

LIMITATION AND FUTURE DIRECTIONS

A possible limiting factor and a possibility for future studies is the monitoring of training through physiological indicators, such as heart rate, or a biochemical indicator to more accurately understand the responses of a body to the stimuli applied, especially the technical training, since it accounts for a large part of the training throughout the season. Another interesting factor to be explored in future research is the recovery indicators between training sessions, such as questionnaires, physiological indicators, and performance tests after the training sessions. We know that the sample of our study is small, but it is difficult to find professional team sports that would accept being part of research throughout the season.

CONCLUSIONS AND PRACTICAL APPLICATIONS

The present study aimed to verify the monitoring of the training effect and to compare the responses of biomotor capabilities at different times of the competitive season. From the collected data, it is possible to conclude that: (i) the proposed training organization was sufficient to improve the lower limb power and the aerobic power of the players and (ii) the dynamics between stimulus and recovery, evidenced by monotony, influenced the performance of the athletes. It is important to highlight the strength of the present study, since there are few studies that analyze training load throughout a season and the behavior of biomotor skills in futsal athletes. In addition, studying sports by high-performance teams within their natural environment is an important step in understanding the responses of all variables involved and providing better advice for coaches.

The production of knowledge having high-performance teams as a source of data has always been an arduous task, especially during a long training period such as the one in this study. In addition, the tools presented here are low cost and easy to use, while also being effective in monitoring training, managing fatigue, and avoiding undesirable adaptations during the season. Coaches and physical trainers must pay attention to the volume of technical and tactical training prescribed so that it does not influence neuromuscular capabilities. This study documented that it is necessary to look beyond the total training load to understand which variable (volume x intensity) should be better dosed; thus, coaches and trainers are advised to look into the variables of training to prescribe exercise to improve performance and apply appropriate workloads during the season and, especially, reducing volume during competitive phases injury risks and decrement of performance.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by UNICAMP. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RS and JB contributed to conception and design of the study. RS organized the database and wrote the first and second draft of the article. JB wrote some sections of manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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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.

frontiers in Psychology

BRIEF RESEARCH REPORT
published: 03 June 2021
doi: 10.3389/fpsyg.2021.625079

The Influence of Forefoot Bending Stiffness of Futsal Shoes on Multiple V-Cut Run Performance

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A forefoot bending stiffness (FBS) property of footwear is known to benefit athletes in running performance. To date, the efficacy of bending stiffness on performance is rather unknown from the perspective of futsal shoes. This study investigates the influence of bending stiffness property of three commercial futsal shoes on change of direction run resultant performance. Nineteen university level athletes participated in the human performance test (multiple V-cut change of direction run) on a hardwood flooring facility using three pairs of futsal shoes (i.e., S1, S2, and S3) with different models but similar in outsole material (S1—mass: 311 g, heel-to-toe drop: 10 mm, friction coefficient, 1.25; S2—mass: 232 g, heel-to-toe drop: 8 mm, friction coefficient: 1.34; and S3—mass: 276 g, heel-to-toe drop: 7 mm, friction coefficient: 1.30). The FBS properties for each shoe were mechanically measured. Results from the analysis of variance indicated that there was a significant difference of FBS value among the three shoes (S1: 0.32 Nm/deg., S2: 0.26 Nm/deg., and S3: 0.36 Nm/deg.) [$F_{(2,8)} = 28.50$ ($p < 0.001$)]. Shoes with relatively higher shoe-playing surface friction coefficient (S2 and S3) had significant impact on the V-cut performance ($p < 0.05$) when compared with the shoe with lower friction coefficient (S1). In contrast to the literature, the shoe with the lowest FBS (S2) did not suffer any detriments on the resultant performance in the test conducted. These findings suggested that there could be other performance limiting factors, such as the friction coefficient, rather than FBS that have greater influence on the test outcomes.

Keywords: futsal shoe, bending stiffness, sole hardness, running, change of direction

OPEN ACCESS

Edited by:
Fábio Yuzo Nakamura, Instituto Universitário da Maia (ISMAI), Portugal

Reviewed by:
Tulio Moura, Núcleo de Alto Rendimento Esportivo de São Paulo (NAR), Brazil
Yaodong Gu, Ningbo University, China

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *02 November 2020*
Accepted: *07 May 2021*
Published: *03 June 2021*

Citation:
Ismail SI, Nunome H and Tamura Y (2021) The Influence of Forefoot Bending Stiffness of Futsal Shoes on Multiple V-Cut Run Performance. Front. Psychol. 12:625079. doi: 10.3389/fpsyg.2021.625079

INTRODUCTION

Similar to soccer, futsal is a sport that demands intermittent high-intensity activity which is based not only on aerobic but also on anaerobic capacity (Bangsbo et al., 1991; Barbero-Alvarez et al., 2008). In a futsal game, players received constant pressure from the opponent players throughout the match, where a 1 vs. 1 situation is common (Vaeyens et al., 2007). Thus, futsal players need to frequently perform a change of direction motion, i.e., turning and other acceleration–deceleration type of movements (Vaeyens et al., 2007). Therefore, the aspect of agility and change of direction capability is crucial in futsal game. Previous studies that compared futsal and soccer players found no significant difference between them on agility and change of direction performances (Milanović et al., 2011; Kartal, 2016). While many studies have focused on the aspect of shoes on soccer performance, there are still only few studies that focus on the influence of shoes on the performance of players in futsal (Kulessa et al., 2017).

Appropriate shoe selection would contribute to improve the performance of players and help them reduce injury risks based on the sport-specific functionality (Lake, 2000). A lower-extremity injury is common in soccer, and the previous study has shown that shoe property can influence biomechanical variables that are related to lower-extremity injuries such as peak dorsiflexion and knee flexion angle (Butler et al., 2014). Among many aspects of a shoe, the importance of bending stiffness has been highlighted in many previous studies where adequate shoe bending stiffness is known to benefit athletes in the running performance (Stefanyshyn and Fusco, 2004; Tinoco et al., 2010; Worobets and Wannop, 2015). It has been known that stiffer shoe configuration helps in reducing the ground reaction force during the push-off phase in running (Willwacher et al., 2014). In addition, higher shoe bending stiffness has also been reported to improve vertical impulse and vertical jump height in a countermovement jump (Roy and Stefanyshyn, 2002). To date, there are several studies on the efficacy of forefoot bending stiffness (FBS) on the running performance for athletic shoes (Stefanyshyn and Fusco, 2004), volleyball shoes (Tinoco et al., 2010), and basketball shoes (Worobets and Wannop, 2015) but none on futsal shoes (Kulessa et al., 2017). Each of the above-mentioned studies has reported positive results when using shoes with higher bending stiffness properties for each respective sport. This feature of futsal shoes also warrants investigation.

In this study, we aimed to generate new information with regards to the commercially available futsal shoes. We also aimed to investigate bending stiffness efficacy on the functionality aspects of futsal shoe. Therefore, the purpose of this case study is to examine futsal shoe bending stiffness influence on multiple V-cut run performance. It was hypothesized that shoe bending stiffness would have a substantial impact on the test outcomes.

TABLE 1 | Properties and features of shoes.

Shoe	S1 (Puma Invicto II) 	S2 (Mizuno Monarcida Sala) 	S3 (Mizuno Monarcida FS) 
Shoe mass (g)	311	232	276
Heel-to-toe drop (mm)	10	8	7
Hardness of outsole [Shore HA (°)]	57	60	60
Available friction coefficient (AFC*)	1.25	1.34	1.30

Data based on the previous study (Ismail et al., 2020), reproduced with permission from the publisher (license number: 4937400524403).

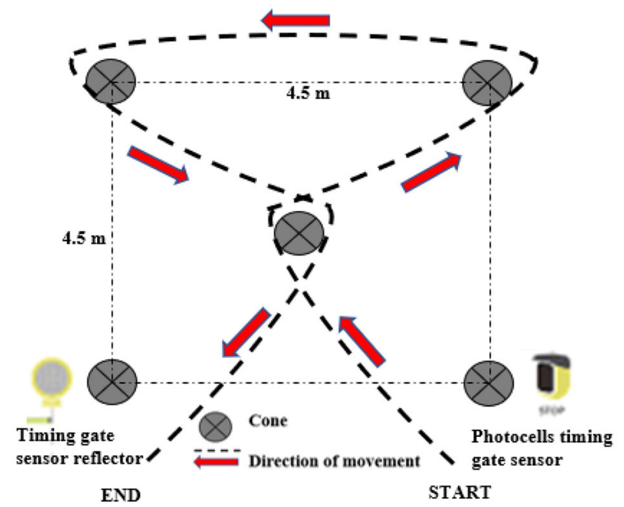

FIGURE 1 | Multiple V-cut pylon course functional test.

MATERIALS AND METHODS

Participants

Nineteen experienced male university level soccer players who regularly participated in competitive national level soccer tournaments (age: 20.2 ± 1.1 years old, body mass: 66.8 ± 6.7 kg, height: 174 ± 5 cm, and soccer experience: 13.6 ± 2 years) were recruited for the multiple V-cut test. All participants were free from any lower limb injuries and active in university level competitions when they participated in this study during the off-season period. All participants provided written informed consent prior to participation in accordance with the research ethical approval obtained from the institutional research ethics committee.

Footwear

Three different models of shoes were selected for this study. The properties and features of each shoe are described in **Table 1**.

The selection criteria for the shoes are as follows: (1) categorized as an indoor soccer/futsal shoes, (2) did not possess midsole construction, (3) possessed similar outsole material and hardness, (4) similar heel-to-toe drop value, (5) available friction coefficient (AFC) differences within ±20%, and (6) mass differences within ±20% and differences below 300 g (Nigg and Enders, 2013; Worobets and Wannop, 2015). These criteria were prerequisite to ensure that all the selected shoes possessed no obvious difference in terms of the shoe construction, and any differences would not provide any obvious advantages/disadvantages during the test conducted in this study.

Change of Direction Run Test and Experimental Procedure

A cutting course similar to that of the study by Worobets and Wannop (2015) was set in a hardwood indoor flooring facility. Before testing, each participant performed an adequate warm-up that was similar to his usual preparation for a match. Each participant was then asked to maximally complete this cutting course consisting of two 90° cut and 135° V-cut maneuvers within a 4.5 m × 4.5 m area (**Figure 1**) using the three types of shoes with different sizes. During the test, the order of shoes was randomized (no two consecutive trials using the same shoe).

TABLE 2 | The mean forefoot bending stiffness of each shoe.

Shoe	Forefoot bending stiffness
	Mean ± (SD) [Nm/degree]
S1	0.32 ± 0.02* (*$p < 0.05$)
S2	0.026 ± 0.01 (*$p < 0.05$; $p < 0.001$)
S3	0.36 ± 0.02 ($p < 0.001$)
ANOVA remarks	$F_{(2,8)} = 28.50$ ($p < 0.001$)

Post-hoc pairwise comparisons.
Significantly different between S1 and S2.
Significantly different between S2 and S3.
All statistical significance level at $p < 0.05$.

The test was repeated with enough intervals (to avoid the effect of fatigue) between trials to obtain three successful trials (no slipping and colliding with cone during trial) for all the three shoes. A photocell timing gate system (Witty System, Microgate, Italy) was utilized to record the resultant time of all the trials. The distance between the participant front foot and the photocell timing gate sensor during the beginning of the trial was fixed at 0.5 m. All the tests were performed on hardwood indoor flooring facilities.

Shoe Forefoot Bending Stiffness Test

The FBS of each shoe was measured using a similar method described in the study by Worobets and Wannop (2015). Each shoe was applied with forefoot bending forces ranging between 2 and 18 Nm in 6–9 stages until all shoes reach a maximum bending angle of more than 40°. All data obtained from these trials were plotted on a bending force–angle graph as the bending force was the independent variable, and a regression line was fit at least to a minimum of six data points. The bending stiffness of each shoe was measured three times, and the mean values were computed as the representing values.

Data and Statistical Analysis

In this study, the results obtained for all the three shoes were compared to observe any differences in terms of the bending stiffness properties and resultant running performances during the change of direction run test.

The statistical analyses were performed using an open-source statistical software, PSPP (GNU project, version 1.0.1). A comparative analysis across the three shoes was conducted with one-way ANOVA repeated measures, and Bonferroni *post-hoc* analysis was applied when required. The statistical significance level was set at $p < 0.05$ for all the analyses.

RESULTS

Forefoot Bending Stiffness

The FBS for each shoe and the comparative analysis across the three shoes (i.e., one-way ANOVA repeated measures with Bonferroni *post-hoc* analysis) are shown in **Table 2**. It was identified that there was a significant difference between the S2 (0.26 Nm/deg.) and the other two shoes [S1: 0.32 Nm/deg. ($p = 0.01$) and S3: 0.36 Nm/deg. ($p < 0.001$)].

Multiple V-Cut Performance

The results obtained from the multiple V-cut run performance test are shown in **Figure 2**. As shown in the figure, there are significant differences among the three shoes for the multiple V-cut performance test [$F_{(2,170)} = 4.60$ ($p = 0.01$)] where the participants performed significantly faster when they used the S2 (4.81 ± 0.3 s: *post-hoc* $p = 0.02$) and S3 shoes (4.83 ± 0.3 s: *post-hoc* $p = 0.03$) than S1 (4.96 ± 0.3 s) while no significant difference was found between S2 and S3 shoes.

DISCUSSION

This study aimed to verify FBS efficacy on the resultant performance in change of direction run task. We hypothesized that different FBS properties would have a substantial impact on the outcomes of the functional performance tests. It was demonstrated surprisingly that FBS is considered to have no substantial impact on the performance tests conducted in this study. Thus, these findings most likely rejected our hypothesis that bending stiffness for the tested shoes in this study would have a substantial impact on multiple V-cut run resultant performance.

Forefoot Bending Stiffness

For the FBS, the S1 shoe with a softer outsole material (57 HA) has shown to possess significantly higher bending stiffness (S1: 0.32 Nm/deg., S2: 0.26 Nm/deg.) when compared with the S2 shoe (60 HA). In addition, we also found a significant difference between S2 and S3 shoes (**Table 2**), where both of them have identical outsole material hardness (60 HA). This finding demonstrated that the hardness of outsole material is not a primary factor to determine the FBS of a shoe. It can be assumed that the stiffness could potentially be modulated by the straight-line groove aspect of the outsoles (Lam et al., 2019). The S1 and S3 shoes do not have aggressive medio-lateral straight-line grooves as S2 shoe. This simplex outsole feature could potentially influence the bending stiffness property of S2. As intended, this feature likely affects its relatively lower bending stiffness when compared with other shoes. The results from this study have demonstrated that the outsole geometrical aspects could have a substantial influence on the FBS of a shoe. In addition, the upper sole material and construction of each shoe could also dictate the FBS properties. Another possible explanation on the lack of influence of the FBS of a shoe on the functional test results is that the FBS of all the shoes selected in this study may be much smaller than the FBS of the participants. If the FBS of a human is larger than the bending stiffness of a shoe, then the total FBS will be dominated by the human foot, thus limiting the influence of the FBS of shoes during the functional test. A similar finding was reported in the literature when it was found that if the FBS of a human is larger than the bending stiffness of the running shoes, then any variations in the bending stiffness of the shoes are unlikely to have a significant influence on running performance (Oleson et al., 2005).

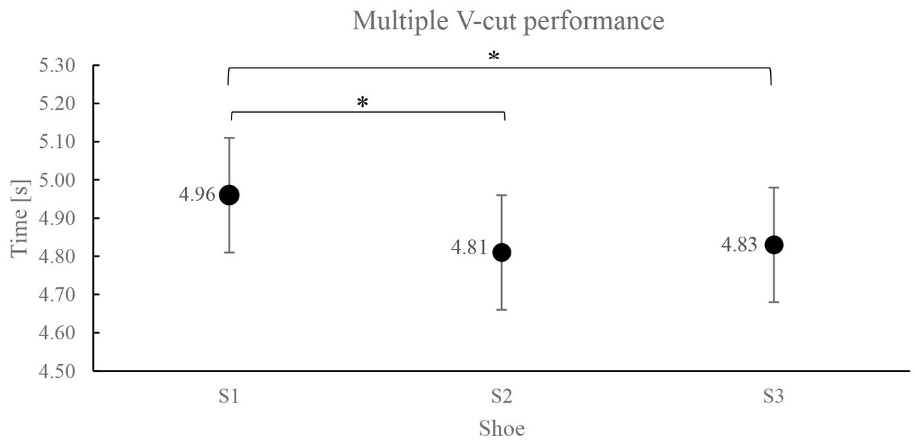

FIGURE 2 | Mean value (±SD) of multiple V-cut performance (*ANOVA: $p < 0.05$).

Multiple V-Cut Performance

It was generally accepted that higher FBS is known to benefit athletes in running performance (Stefanyshyn and Fusco, 2004; Tinoco et al., 2010; Worobets and Wannop, 2015; Day and Hahn, 2020). The studies by Worobets and Wannop (2015) and Day and Hahn (2020) have reported the FBS values (0.10–0.29 Nm/deg. and 0.22–0.33 Nm/deg., respectively) by using a similar method performed in this study. Both studies reported that higher FBS significantly improved running performances. In this study, however, the differences in FBS of the tested shoes do not seem to play a dominant role for running performance because the shoe with the lowest FBS (S2) did not suffer any detriments on resultant performance in change of direction results. The contradicting results found in this study may be due to the fact that these two previous studies (Worobets and Wannop, 2015; Day and Hahn, 2020) applied systematic ways to solely alter the shoe bending stiffness. Under this circumstance, only the FBS property of the tested shoes was altered while retaining the shoe property identical. On the contrary, in this study, an attempt was made to compare commercially available shoes across different models but with similar features and construction. Based on this evidence, it can be speculated that that there could be other performance limiting factors rather than FBS which have influenced the test outcomes during the multiple V-cut change of direction.

Influence of Shoe Mass

The previous study has verified that increasing the shoe mass would predictably reduce running performance from the energetic point of view (Hoogkamer et al., 2016). From the perspective of sprint and cutting performances, the effect of shoe mass seems to have some threshold. The study by Nigg and Enders (2013) on sports footwear found that only shoe mass becomes an important factor for the weight difference of above 300 g in running performance. This finding has been supported by other similar studies. Recent study by Köse (2018) verified that the weight difference of 285 g between two shoes has shown a significant effect on 10-m sprint performance. In another study on basketball shoe, it was reported that the shoe within 20% of weight difference did not significantly influence the sprint and cutting performances (Worobets and Wannop, 2015). Since the three shoes used in this study are within 20% of weight differences (below 285 g of weight differences), it was concluded that the influence of shoe mass is less than small or non-existent due to small weight differences.

Influence of Heel-to-toe Drop

The three shoes selected for this study possess relatively small heel-to-toe drop differences (7–10 mm) when compared with one another. While it could not be identified precisely how this small difference could influence the study outcomes, the only possibility that exist is the shoe with higher heel-to-toe drop could possibly offer a slight extra cushioning feature to the shoe. However, the study by Lam et al. (2017) identified that cushioning provides no advantage to the horizontal ground reaction force component that is crucial during short-exertion, high-intensity movement such as short-distance sprint and change of direction tasks. Therefore, it can be suggested that the influence of heel-to-toe drop difference was minimal in this study.

Influence of Available Friction Coefficient

The three shoes selected in this study were also selected in other previous study (Ismail et al., 2020), where the available traction (the AFC) of all the shoes were mechanically measured. The influence of AFC on change of direction and perceived traction performances was observed in the study by Ismail et al. (2020). It was reported that AFC possessed substantial influence on the change of direction and perceived traction performances. Similarly, as reported in this study, Ismail et al. (2020) reported that participants have performed significantly better when using S2 (AFC: 1.34) and S3 (AFC: 1.30) shoes as compared with S1 shoe (AFC: 1.25). Thus, it was suggested that differences on the AFC component between the shoes of S1 and S2 as well as S1 and S3 could potentially influence the outcomes of the study. Currently, there is no existing study that has compared the influence of both AFC and FBS on change of direction performance. Therefore, it is still difficult to establish a clear conclusion, but as observed in this study and previous study (Ismail et al., 2020) it can be speculated that AFC could potentially possess a much dominant influence on change of direction performance as compared with FBS.

Study limitation

This study focused only on the commercially available futsal shoes to provide more practical, user-friendly information. Although careful selection criteria to pick three different futsal shoes representing similar features were made, several factors, including outsole groove patterns and shoe upper materials and construction, were not systematically controlled. Therefore, the results observed in this study might not be generalized for all types of futsal shoes. More testing on various futsal shoe model is warranted. In addition, we tested the shoe with only one playing surface (hardwood). The tests on different types of futsal playing surfaces (e.g., vinyl, plastic-based, or rubberized material) should be warranted in future studies.

CONCLUSION

In this study, it was demonstrated that FBS may not have systematic influence on resultant performance of the multiple V-cut run. Other possible factors such as mass and heel-to-toe drop properties of shoes were also considered as not having substantial influence on the performance tested in this study. This is likely due to the fact that the property of tested shoes, namely the AFC, possessed the performance limiting factors, namely, mass or heel-to-toe drop properties, rather than FBS. The AFC of a futsal shoe could possess a high dominant effect on change of direction performance rather than FBS.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Fukuoka University, Fukuoka, Japan. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SI has conducted the research conceptualization and data collection, and written the main section of the manuscript. HN and YT have substantially contributed to the supervision, design of the work, and critical review and discussion of the manuscript. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We would like to thank Mizuno Corporation for sponsoring the footwear.

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Conflict of Interest: The authors declare that this study received funding from Mizuno Corporation. Mizuno Corporation had the following involvement with the study: sponsoring the footwear used in the study. Mizuno Corporation was not involved in the study design, collection, analysis, interpretation of data, the writing of this article, or the decision to submit it for publication.

frontiers in Psychology

ORIGINAL RESEARCH
published: 14 June 2021
doi: 10.3389/fpsyg.2021.658996

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Comprehensive Lower Extremities Joints Range of Motion Profile in Futsal Players

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OPEN ACCESS

Edited by:
Fábio Yuzo Nakamura, Instituto Universitário da Maia (ISMAI), Portugal

Reviewed by:
José Afonso, University of Porto, Portugal
Carlos Lago-Fuentes, Universidad Europea del Atlántico, Spain

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *26 January 2021*
Accepted: *17 May 2021*
Published: *14 June 2021*

Citation:
Cejudo A, Ruiz-Pérez I, Hernández-Sánchez S, De Ste Croix M, Sainz de Baranda P and Ayala F (2021) Comprehensive Lower Extremities Joints Range of Motion Profile in Futsal Players. Front. Psychol. 12:658996. doi: 10.3389/fpsyg.2021.658996

The purposes of this study were to describe the lower extremities joints range of motion (ROM) profile using a comprehensive approach in futsal players and to examine potential player position (goalkeepers vs. outfield players), competitive level (first [top] division vs. second division), number of playing years, sex (males vs. females), and bilateral (dominant limb vs. non-dominant limb) differences. A total of 72 male and 67 female elite futsal players from 11 clubs were measured of passive hip (flexion with knee flexed [HF_{KF}] and extended [HF_{KE}], extension [HE], abduction [HA], external [HER], and internal [HIR] rotation), knee (flexion [KF]) and ankle (dorsiflexion with knee flexed [ADF_{KF}] and extended [ADF_{KE}]) ROMs. Bayesian inferences exploring differences between player position, competitive level, sex and limb were made. A Bayesian correlation analysis was conducted to explore the influence of playing years on joints ROMs. The results showed no significant player position or competitive level related differences in any average ROM score. However, statistically significant sex-related differences were documented whereby female players reported higher hip and knee joints ROM average values than their male counterparts. Especially relevant were the proportions of males (72%) and players from teams engaged in the second division (61%) displaying limited HF_{KE} ROMs. Likewise, around 35% of all players showed restricted ADF_{KF} ROMs. In addition, approximately 21, 18, 22, and 25% of the futsal players were identified as having bilateral asymmetries (≥8°) for HA, HIR, HER, and KF ROMs, respectively. Finally, Bayesian correlation analysis did not report any significant association between years of playing futsal and ROM measures (all r values < 0.34). The implications that these restricted HF_{KE} and ADF_{KF} ROMs and bilateral asymmetries in hip (abduction, internal and external rotation) and knee (flexion) ROMs caused by the practice of futsal may have on physical performance and injury risk warrant future research.

Keywords: futsal, muscle flexibility, injury risk, soft tissue injuries, rehabilitation

INTRODUCTION

Futsal (the five-a-side version of associated football) is played worldwide with more than one million registered players all over the world (FIFA, 2007). During the game of futsal, players perform a substantive number of repeated high intensity unilateral actions (e.g., sudden accelerations and decelerations, rapid changes of direction, tackling and kicking) (Dogramaci and Watsford, 2006; Castagna et al., 2009; Beato et al., 2016; Naser et al., 2017). Such high intensity actions alongside lateral preference (e.g., preferred kicking leg) might lead players to progressively develop futsal-specific soft tissue adaptations (Maloney, 2019). In particular, most of these actions impose strong and asymmetric tensile loads on the muscles around the hip, knee, and ankle joints. When these actions are repeated several times during training sessions and matches, they may have the potential to generate changes in the mechanical (e.g., stiffness) and neural (e.g., tolerance to changes in resting length) properties of one or some of the muscle groups (mainly biarticular) involved in them (Witvrouw et al., 2004). Thus, it may be plausible that these muscle adaptations are likely to result in the development of a futsal-specific lower extremities joints range of motion (ROM) profile that might be characterized by the presence of some restricted or limited ROMs and significant bilateral asymmetries (dominant limb vs. non-dominant limb). Furthermore, this hypothetical futsal-specific lower extremities ROM profile may become more evident at elite levels, mainly attributed (but not exclusively) to the higher physical demands of the game and larger number of training sessions per week that players at these levels are usually exposed to Mohammed et al. (2014), Ribeiro et al. (2020), Spyrou et al. (2020). Likewise, the well-documented sex-related anatomical (Hahn and Foldspang, 1997), hormonal (Wojtys et al., 1998), and neuromuscular (Komi and Karlsson, 1978) differences may lead female futsal players to develop a different lower extremities ROM profile in comparison with their male counterparts.

It has been traditionally suggested that studies aimed at describing the effects of long-standing participation within a single sport on major joints ROMs are of interest because restricted values and bilateral asymmetries are not only detrimental to physical performance but also increase the risk of soft tissue injury (Bishop et al., 2018; Afonso et al., 2020). However, from a physical performance standpoint the available evidence does not support such association. In this sense, the findings reported by the studies that have addressed this issue in intermittent team-sport athletes (mainly football and basketball players) are often contradictory, whereby for the same physical performance measure (e.g., jump height), some studies exhibited negative associations (García-Pinillos et al., 2015; Mills et al., 2015) while others did not find a clear influence (Domínguez-Díez et al., 2021) and even better scores were observed in players with poor ROM values (Rey et al., 2016). On the other hand, a growing number of prospective studies have been recently published using contemporary Machine Learning techniques (e.g., supervised learning algorithms) and resampling methods (e.g., fivefold cross validation, leave-one-out, bootstrapping) to build valid and generalizable screening models (area under the receiver operator characteristics [ROC] scores > 0.700) to predict non-contact soft-tissue lower extremities injuries in intermittent team-sport athletes (including futsal players) (Fousekis et al., 2011; López-Valenciano et al., 2018; Rossi et al., 2018; Ayala et al., 2019; Oliver et al., 2020; Rommers et al., 2020; Ruiz-Pérez et al., 2021). Among these studies, those that provided learning algorithms the opportunity to select (or not) measures of ROMs to build prediction models have identified some restricted lower extremities hip (flexion), knee (flexion), and ankle (dorsiflexion) ROMs and bilateral asymmetries as primary predictors of non-contact soft-tissue injury (mainly thigh muscle strains and knee and ankle ligament sprains and tears) in football (López-Valenciano et al., 2018; Ayala et al., 2019), handball (López-Valenciano et al., 2018), and futsal players (Ruiz-Pérez et al., 2021). Therefore, and with a certain degree of caution, it could be stated that knowing whether (or not) futsal players may develop sport-specific adaptations from training and matches that would cause significant impairments and bilateral differences in lower extremities joints ROMs might help coaches and sport scientists in the decision-making process for injury prevention.

Only Cejudo et al. (2014) have described the lower extremities ROM profile in elite male futsal players. The results shown in this study indicate that the practice of futsal did not elicit clinically relevant impairments in hip, knee and ankle joints ROM average values in this cohort of players. Likewise, no statistically significant bilateral differences were found for the joint ROMs of the dominant and non-dominant limbs. However, the lower extremities ROM profile described by Cejudo et al. (2014) should be considered with a degree of caution since only 20 players from a single futsal team were used, which may reduce its external validity. In addition, Cejudo et al. (2014) only provided average values so that the possible inter-player variability in joint ROMs was not considered and thus, it may distort the true extent of the number of players reporting restricted ROMs. In an attempt to minimize the effects of inter-player variability and achieve a more realistic diagnosis regarding the presence (or absence) of changes in ROMs attributed to intensive sport practice, López-Valenciano et al. (2019) suggested using a new comprehensive profile of joint ROMs. In this profile not only ROM average scores are reported but also the number of players showing bilateral asymmetries (between-limb differences > 6–10°) (Fousekis et al., 2011; López-Valenciano et al., 2019) and normal and limited (based on the previously published cutoff scores to classify athletes at high risk of injury) ROM values.

Therefore, the purposes of this study were to describe the lower extremities joints ROM profile using a comprehensive approach in a large cohort of futsal players and to examine potential player position (goalkeepers vs. outfield players), competitive level (first [top] division vs. second division), number of playing years, sex (males vs. females), and bilateral (dominant limb vs. non-dominant limb) differences.

MATERIALS AND METHODS

Participants

A convenience sample of 139 (72 males and 67 females) elite futsal players from 12 different teams (56 players [24 males and 32 females] from six clubs engaged in the First [top] National Spanish Futsal division and 83 players [48 males and 35 females] from six clubs engaged in the Second National Futsal division) completed this study. Before data collection, participants filled out a questionnaire containing questions about their sport-related background (player position, the current competitive level, dominant leg, sport experience), anthropometric characteristics (age, body mass, and stature) and training regimen (weekly practice frequency, hours of futsal practice per week and day, number of playing years). Descriptive statistics for males and females are displayed in **Table 1**. The exclusion criterion was history of orthopedic problems to the knee, thigh, hip, or lower back in the month before the study from which players were considered (by teams' medical staff) as not fully recovered and whose acute residual symptoms could have a temporary impact on the habitual players' movement competency and/or lower extremities ROM profile (López-Valenciano et al., 2019; Moreno-Pérez et al., 2020). The study was conducted at the end of the pre-season phase in 2015 (39 male [4 teams] players), 2016 (26 male [2 teams] and 18 female [2 teams] players), 2017 (7 male [1 team] and 23 female [2 teams] players) and 2018 (26 female [2 teams] players) (September). Only one pre-season ROM assessment was carried out in 121 out of 139 players through the 4-year length of the study while 18 female players from the same team were assessed twice in different years (2017 and 2018). The time frame of the study was selected to be sure that the players recruited to each team were definitive and stable within the testing period. Before any participation, experimental procedures and potential risks were fully explained to the players and coaches in verbal and written form and written informed consent was obtained from players. An Institutional Research Ethics committee approved the study protocol prior to data collection (DPS.FAR.01.14) conforming to the recommendations of the Declaration of Frontera.

Testing Procedure

The passive hip flexion with knee flexed (HF_{KF}) and extended (HF_{KE}), extension (HE), abduction (HA), external (HER) and internal (HIR) rotation; knee flexion (KF); and ankle dorsiflexion with knee flexed (ADF_{KF}) and extended (ADF_{KE}) ROMs of the dominant and non-dominant limbs were assessed following the methodology previously described (Cejudo et al., 2020). Briefly, an ISOMED inclinometer (Portland, Oregon) with a telescopic arm was used as the key measure for all tests. The inclinometer was consistently placed level before each measurement to assure that no change occurred in the sensitivity. A low-back protection sup- port (Lumbosant, Murcia, Spain) was used to standardize the lordotic curve (15°) during all the assessment tests. Variations in pelvic position and stability may affect the final score of several measurements of hip movement range of motion (Bohannon et al., 1985). Thus, to accurately measure hip joint ROMs, the assessment procedure in this study provided suitable stabilization of the pelvis during all the tests using an assistant clinician.

The dominant limb was defined as the participant's preferred kicking leg (self-reported). Prior to the testing session, all participants performed the dynamic warm-up designed by Taylor et al. (2009). The overall duration of the entire warm-up was approximately 20 min. The assessment of the nine ROMs was carried out 3–5 min after the dynamic warm-up. After the warm-up, participants were instructed to perform, in a randomized order, two maximal trials of each ROM test for each limb, and the mean score for each test was used in the analyses. When a variation $> 4°$ was found in the ROM values between the two trials of any test, an extra trial was performed, and the two most closely related trials were used for the subsequent statistical analyses. One or both of the following criteria determined the endpoint for each test: (a) palpable onset of pelvic rotation, and/or (b) the participant feeling a strong but tolerable stretch, slightly before the occurrence of pain. Participants were examined wearing sports clothes and without shoes. A 30 s rest was given between trials, limbs and tests. All tests were carried out by the same two sports science specialists under stable environmental conditions. Standardization procedures (including the warm-up, test setup, and participant instructions) were replicated at each test session conducted in the different clubs. Teams' performance staff were told not to request players to perform high intensity activities at least 48 h before testing sessions to minimize the impact of potential muscle soreness and contractures on ROM scores. All testing sessions were carried out within the 2 weeks before the beginning of the futsal in-season and always in the late afternoon or evening (according to each team' training schedules).

TABLE 1 | Demographic variables (mean ± SD) for the elite futsal players.

Variable	Males (n = 72)	Females (n = 67)
Age (years)	22.8 ± 5.5	22.3 ± 4.5
Stature (cm)	177.6 ± 6.4	164.6 ± 5.8
Body mass (kg)	73.1 ± 6.6	60.2 ± 6.7
Years playing futsal (years)	13.8 ± 5.1	13.2 ± 4.4
Weekly practice frequency	4.1 ± 0.6	3.1 ± 0.4
Hours of futsal practice per week	10.8 ± 1.7	8.4 ± 1.0

SD, standard deviation.

Statistical Analysis

Statistical analyses were performed using JASP software version 0.13.01 (Amsterdam, Netherland). Prior to the statistical analysis, the distribution of raw data sets was checked using the Shapiro–Wilk expanded test and demonstrated that all data had a normal distribution ($p > 0.05$). Descriptive statistics (including means and standard deviations [SD]) were calculated for hip, knee and ankle ROM measures for all futsal players combined and also separately by player position (goalkeepers vs. outfield players), competitive level (first division vs. second division) and sex (males vs. females).

Separate Bayesian paired samples t-tests were carried out to determine the existence of significant bilateral differences in hip, knee and ankle average ROMs. Likewise, Bayesian independent samples t-tests were conducted to explore differences in ROM average scores between player position, competitive level and sex. For all the Bayesian inference tests run, the BF_{10} was interpreted using the evidence categories previously suggested (Wagenmakers et al., 2018): $< \frac{1}{100}$ = extreme evidence for null hypothesis (H_0 = no main effects), from $\frac{1}{100}$ to $< \frac{1}{30}$ = very strong evidence for H_0, from $\frac{1}{30}$ to $< \frac{1}{10}$ = strong evidence for H_0, from $\frac{1}{10}$ to $< \frac{1}{3}$ = moderate evidence for H_0, from $\frac{1}{3}$ to < 1 anecdotical evidence for H_0, from 1 to 3 = anecdotical evidence for alternative hypothesis (H_1), from >3–10 = moderate evidence for H_1, from >10 to 30 = strong evidence for H_1, from >30–100 = very strong evidence for H_1, $>$ 100 extreme evidence for H_1. Only those models that showed at least strong evidence for supporting H_1 ($BF_{10} > 10$) with a percental error < 10 were considered robust enough to describe the main effects.

Furthermore, and similar to what was carried out in previous studies on football players (Ayala et al., 2019; Robles-Palazón et al., 2020), in each participant, the hip, knee and ankle ROM scores were categorized as normal (i.e., non-pathologic) or limited according to the reference values previously reported to consider an athlete as being more prone to suffer an injury. Thus, ROM values were reported as limited according to the following cut-off scores: <114° (limited) and ≥114° (normal) for the HF_{KF} ROM (Holla et al., 2012) , <80° (limited) and ≥80° (normal) for the HF_{KE} ROM (Kendall et al., 2005), <50° (limited) and ≥50° (normal) for the HA ROM (Gerhardt et al., 2002), <26° (limited) and ≥26° (normal) for the HIR ROM (Roach et al., 2013), <30° (limited) and ≥30° (normal) for the HER ROM (L'Hermette et al., 2006), <0° (limited) and ≥0° (normal) for the HE ROM (Young et al., 2004), <120° (limited) and ≥120° (normal) for the KF ROM (Peat et al., 2007), <17° (limited) and ≥17° (normal) for the ADF_{KE} ROM (Ekstrand and Gillquist, 1982; Kibler et al., 1988) and <34° (limited) and ≥34° (normal) for the ADF_{KF} ROM (Pope et al., 1998). In those ROMs in which different cut-off scores have been described in the literature to categorize athletes as having either high or moderate risk of soft-tissue injury, the most restrictive one was selected as the cut-off score for the current study. The cut-off scores previously suggested by Robles-Palazón et al. (2020) were used to calculate the number and percentage of players with bilateral differences (≥8°) in each ROM. For each ROM, percentage scores larger than 20% of players showing limited values and significant bilateral differences were considered for this study as relevant from an injury prevention standpoint. In each ROM in which the percentage of players showing limited values and/or significant bilateral differences were larger than 20%, a Bayesian Pearson's chi-squared (x^2) test was used to examine potential player position (goalkeepers vs. outfield players), competitive level (first [top] division vs. second division) and sex (males vs. females) -related differences in the proportion of players showing limited scores and bilateral differences.

Finally, a Bayesian correlation analysis was performed to examine the correlation between participants' years of playing futsal and each ROM score. Magnitudes of correlations were assessed using the following scale of thresholds: <0.80 = low, 0.80–0.90 = moderate, and >0.90 = high (Hopkins, 2000).

RESULTS

Tables 2–5 display the descriptive ROM values for hip (HF_{KF}, HF_{KE}, HA, HIR, HER and HE), knee (KF), and ankle (ADF_{KF} and ADF_{KE}) joints for all players combined and separately by player position, competitive level and sex, respectively.

With all players combined, Bayesian paired samples t-tests did show no significant differences ($BF_{10} < 10$) between dominant and non-dominant limbs for each of the nine ROMs (**Table 2**). Consequently, the ROM average score for both limbs was used for between-group comparisons. There were no significant differences in the hip, knee and ankle joints ROM values obtained from goalkeepers and outfield players (**Table 3**). Likewise, there were also no significant competitive level related differences in any of the ROMs (**Table 4**). However, statistically significant

TABLE 2 | Descriptive values and inter-limb differences for hip (flexion, extension, abduction, internal, and external rotation), knee (flexion), and ankle (dorsalflexion with knee flexed and extended) ranges of motion for all futsal players combined (n = 139).

Range of motion (°)	Dominant limb		Non-dominant limb		Inter-limb differences	
	Mean ± SD	Qualitative outcome[a]	Mean ± SD	Qualitative outcome[a]	Mean and 95% CI	Players with bilateral differences ≥ 8°
HF_{KF}	136.1 ± 9.5	Normal (1/139)	137.4 ± 9.3	Normal (1/139)	–1.3 (–2.1 to –0.4)	21/139 (15%)
HF_{KE}	83.2 ± 16	Normal (66/139)	82.9 ± 15.3	Normal (62/139)	0.3 (–0.6 to 1.2)	24/139 (17%)
HA	64.4 ± 11.8	Normal (12/139)	63.4 ± 12.6	Normal (12/139)	1 (–0.1 to 1.9)	29/139 (21%)
HIR	47.6 ± 10.4	Normal (2/139)	46.7 ± 10.9	Normal (1/139)	0.9 (–0.3 to 2)	39/139 (28%)
HER	57.8 ± 9.2	Normal (0/139)	57.2 ± 10.1	Normal (0/139)	0.7 (–0.5 to 1.8)	30/139 (22%)
HE	14.6 ± 7.5	Normal (3/139)	15.1 ± 7.5	Normal (3/139)	–0.5 (–0.9 to –0.1)	4/139 (3%)
KF	128.4 ± 11.3	Normal (0/139)	126.3 ± 10.6	Normal (0/139)	2.1 (0.9 to 3.2)	35/139 (25%)
ADF_{KE}	33.9 ± 5.4	Normal (1/139)	33.2 ± 4.8	Normal (0/139)	0.6 (0 to 1.2)	10/139 (7%)
ADF_{KF}	35.8 ± 5.6	Normal (49/139)	36 ± 5.8	Normal (45/139)	–0.2 (–0.7 to 0.4)	7/139 (5%)

HF_{KF}, hip flexion with knee flexed test; HF_{KE}, hip flexion with knee extended test; HA, hip abduction test; HIR, hip internal rotation test; HER, hip external rotation test; HE, hip extension test; KF, knee flexion test; ADF_{KE}, ankle dorsiflexion with knee extended test; ADF_{KF}, ankle dorsiflexion with knee flexed test. °, degrees; [a], qualitative score of the mean range of motion, in parentheses the number of players with a limited range of motion score according to previously published cut-off scores (see section "Statistical analysis").

TABLE 3 | Descriptive values and number (percentage) of players with bilateral differences ≥ 8° for hip (flexion, extension, abduction, internal and external rotation), knee (flexion), and ankle (dorsal-flexion with knee flexed and extended) ranges of motion separately by player position.

Range of motion (°)	Goalkeepers (n = 31)			Outfield players (n = 108)		
	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°
HF_{KF}	138.1 ± 10.2	Normal (0/31)	3/31 (10%)	136.1 ± 9.8	Normal (1/108)	18/108 (17%)
HF_{KE}	87.5 ± 16.2	Normal (13/31)	6/31 (19%)	83.2 ± 16.5	Normal (53/108)	18/108 (17%)
HA	69.7 ± 10.9	Normal (0/31)	5/31 (16%)	63.6 ± 12.3	Normal (12/108)	24/108 (22%)
HIR	48.6 ± 8.8	Normal (0/31)	7/31 (23%)	47.9 ± 11.2	Normal (2/108)	32/108 (30%)
HER	61.1 ± 8.7	Normal (0/31)	7/31 (23%)	57.5 ± 9.7	Normal (0/108)	23/108 (21%)
HE	16.4 ± 8.2	Normal (1/31)	2/31 (6%)	14.5 ± 7.6	Normal (2/108)	2/108 (2%)
KF	131 ± 8.7	Normal (4/31)	8/31 (26%)	128.1 ± 12.4	Normal (22/108)	27/108 (25%)
ADF_{KE}	33 ± 6.8	Normal (0/31)	3/31 (10%)	34.1 ± 5.2	Normal (0/108)	7/108 (7%)
ADF_{KF}	34.2 ± 6.2	Normal (13/31)	0/31 (0%)	36.1 ± 5.6	Normal (36/108)	7/108 (7%)

HF_{KF}, hip flexion with knee flexed test; HF_{KE}, hip flexion with knee extended test; HA, hip abduction test; HIR, hip internal rotation test; HER, hip external rotation test; HE, hip extension test; KF, knee flexion test; ADF_{KE}, ankle dorsiflexion with knee extended test; ADF_{KF}, Ankle dorsiflexion with knee flexed test. °, degrees; [a], qualitative score of the mean range of motion, in parentheses the number of players with a limited range of motion score according to previously published cut-off scores (see section "Statistical analysis"). 9

TABLE 4 | Descriptive values and number (percentage) of players with bilateral differences ≥ 8° for hip (flexion, extension, abduction, internal and external rotation), knee (flexion), and ankle (dorsal-flexion with knee flexed and extended) ranges of motion separately by competitive level.

Range of motion (°)	First division (n = 56)			Second division (n = 83)		
	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°
HF_{KF}	138.2 ± 10	Normal (0/56)	11/56 (20%)	134.7 ± 8.9	Normal (0/83)	10/83 (12%)
HF_{KE}	86.1 ± 14.4	Normal (15/56)	13/56 (23%)	81.2 ± 16.8	Normal (51/83)	11/83 (13%)
HA	64.9 ± 11.8	Normal (6/56)	16/56 (29%)	64.1 ± 11.9	Normal (6/83)	13/83 (16%)
HIR	48.5 ± 9.9	Normal (1/56)	14/56 (25%)	46.9 ± 10.7	Normal (1/83)	25/83 (30%)
HER	59.9 ± 10.1	Normal (0/56)	13/56 (23%)	56.4 ± 8.4	Normal (0/83)	17/83 (21%)
HE	12.6 ± 6.6	Normal (1/56)	3/56 (5%)	15.9 ± 7.8	Normal (2/83)	1/83 (1%)
KF	125.3 ± 9.2	Normal (13/56)	11/56 (20%)	130.4 ± 12.1	Normal (13/83)	24/83 (29%)
ADF_{KE}	34 ± 5.5	Normal (1/56)	4/56 (7%)	33.8 ± 5.4	Normal (0/83)	6/83 (7%)
ADF_{KF}	35.2 ± 4.8	Normal (22/56)	4/56 (7%)	36.3 ± 6	Normal (27/83)	3/83 (4%)

HF_{KF}, hip flexion with knee flexed test; HF_{KE}, hip flexion with knee extended test; HA, hip abduction test; HIR, hip internal rotation test; HER, hip external rotation test; HE, hip extension test; KF, knee flexion test; ADF_{KE}, ankle dorsiflexion with knee extended test; ADF_{KF}, ankle dorsiflexion with knee flexed test. °, degrees; [a], qualitative score of the mean range of motion, in parentheses the number of players with a limited range of motion score according to previously published cut-off scores (see section "Statistical analysis").

sex-related differences were documented whereby female players reported higher hip and knee joints ROM average values than their male counterparts (**Table 5**).

The comprehensive analysis conducted in this study found that a significant number of the futsal players (independently of the player position, competitive level and sex) demonstrate limited HF_{KE} (≈47%) and/or ADF_{KF} (35%) ROMs (**Table 2**). In addition, approximately 21, 18, 22, and 25% of the futsal players were identified as having bilateral asymmetries (≥8°) for HA, HIR, HER, and KF ROMs, respectively. Inter-group comparisons showed that percentages larger than 40% of the goalkeepers and outfield players recruited in this study presented limited HF_{KE} and ADF_{KF} ROMs. Likewise, significant bilateral differences in HIR and HER ROMs were observed for 23% of the goalkeepers and 23% (HIR ROM) and 30% (HER ROM) of the outfield players. The Bayesian x^2 tests did not show significant differences between the proportions of goalkeepers and outfield players with limited HF_{KE} and ADF_{KF} ROMs nor between those goalkeepers and outfield players who displayed bilateral differences ≥ 8° in these two ROMs. Approximately 26, 23, and 39% of players from teams engaged in the first division reported limited HF_{KE}, KF and ADF_{KF} ROM values, respectively. Furthermore, percentages of first division players ranged from 23 to 29% presented significant bilateral differences in their HF_{KE}, HA, HIR, and HER ROMs. For its part, a percentage larger than 20% of the players from teams engaged in the second division showed limited HF_{KE} (77%) and ADF_{KF} (32%) ROMs as well as bilateral differences ≥ 8° in their HIR (30%), HER (31%), and KF (29%) ROMs. Significant differences in the proportion of first and second division players with limited ROM values were only found for the HF_{KE} ROM (23% [first division] vs. 77% [second division]) ($BF_{10\ Poisson} > 10$). However, no significant differences were found between the proportions of first division and second division players who displayed bilateral differences ≥ 8° in their

TABLE 5 | Descriptive values and number (percentage) of players with bilateral differences ≥ 8° for hip (flexion, extension, abduction, internal and external rotation), knee (flexion), and ankle (dorsal-flexion with knee flexed and extended) ranges of motion separately by sex.

Range of motion (°)	Males (n = 72)			Females (n = 67)		
	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°	Mean ± SD	Qualitative outcome[a]	Players with bilateral differences ≥ 8°
HF_{KF}*	132.3 ± 9.2	Normal (1/72)	6/72 (8%)	140.2 ± 8.2	Normal (0/67)	15/67 (22%)
HF_{KE}*	74.1 ± 9.7	Limited (52/72)	10/72 (14%)	92.9 ± 15.8	Normal (14/67)	14/67 (21%)
HA*	58.4 ± 7.6	Normal (10/72)	13/72 (18%)	70.9 ± 12.1	Normal (2/67)	16/67 (24%)
HIR*	41.8 ± 6.8	Normal (1/72)	13/72 (18%)	53.8 ± 10.0	Normal (1/67)	26/67 (39%)
HER*	54 ± 7.6	Normal (0/72)	17/72 (24%)	61.9 ± 9.2	Normal (0/67)	13/67 (19%)
HE*	11.9 ± 6.3	Normal (2/72)	0/72 (0%)	17.6 ± 7.5	Normal (1/67)	4/67 (6%)
KF*	125.4 ± 9.7	Normal (17/72)	13/72 (18%)	131.6 ± 12.1	Normal (9/67)	22/67 (33%)
ADF_{KE}	33.4 ± 4.5	Normal (0/72)	3/72 (4%)	34.3 ± 6.2	Normal (1/67)	7/67 (10%)
ADF_{KF}	35.7 ± 5.6	Normal (25/72)	3/72 (4%)	36 ± 5.6	Normal (24/67)	4/67 (6%)

*HF_{KF}, hip flexion with knee flexed test; HF_{KE}, hip flexion with knee extended test; HA, hip abduction test; HIR, hip internal rotation test; HER, hip external rotation test; HE, hip extension test; KF, knee flexion test; ADF_{KE}, ankle dorsiflexion with knee extended test; ADF_{KF}, ankle dorsiflexion with knee flexed test. °, degrees; [a], qualitative score of the mean range of motion, in parentheses the number of players with a limited range of motion score according to previously published cut-off scores (see section "Statistical analysis"). *, statistically significant differences (BF_{10} > 10) between sex (males vs. females).*

ROMs. Approximately 72, 24, and 35% of the male players displayed restrictions in their HF_{KE}, KF and ADF_{KF} ROM values, respectively. For females, 21 and 36% of them reported limited HF_{KE} and ADF_{KF} ROM values. The proportion of female players with limited HF_{KE} ROM values was significantly lower than that of males ($BF_{10\ Poisson} > 10$). Likewise, 24% of the male players showed significant bilateral differences in their HER ROM whereas 22, 21, 24, 39, and 32% of the females presented inter-limb differences ≥ 8° in their HF_{KF}, HF_{KE}, HA, HIR and KF ROMs. The proportion of female players with bilateral differences ≥ 8° in the HF_{KE} and HIR was significantly higher than that of males (18% [males] vs. 39% [females] and 18% [males] vs. 32% [females] for HIR and HF_{KE}, respectively).

Finally, Bayesian correlation analysis did not report any significant correlation between years of playing futsal and ROM measures (all r values < 0.34).

DISCUSSION

The findings of this study indicate that the average values of the nine ROMs assessed in the futsal players may be categorized as normal or non-limited according to the cutoff scores described in the literature to identify athletes at high risk of sustaining a soft-tissue injury. Similar results were found by Cejudo et al. (2014), who after having carried out the same ROM maneuvers and testing procedures [ROM-Sport protocol (Cejudo et al., 2020)] in male futsal players, found hip, knee and ankle ROM average values that may be categorized as normal. From this standpoint, no specific adaptations in the lower extremities joints ROM would be expected as a consequence of futsal training and match play at elite levels. However, when a comprehensive analysis is carried out, the current ROM data shows that a significant number of the futsal players demonstrate limited HF_{KE} (≈47%) and/or ADF_{KF} (≈35%) ROMs, irrespective of their position, competitive level and sex. Previous studies using the same comprehensive analysis employed in the current study also identified a large number of youth (Robles-Palazón et al., 2020) and adult (López-Valenciano et al., 2019) male football players with limited HF_{KE} (≈45%) and/or ADF_{KF} (30%) ROMs, despite the fact that their pooled average scores for these two ROMs were categorized as normal or non-limited [HF_{KE} > 80° (Kendall et al., 2005) and ADF_{KF} > 34° (Pope et al., 1998)]. Therefore, collectively these findings support the statement that an accurate diagnosis of the sport-specific adaptations in the lower extremities joints ROM requires reporting not only ROM average scores but also the number of athletes showing limited (based on the previously published cutoff scores to classify athletes at high risk of injury) ROMs. Similar to that which has been argued for football players, a plausible explanation for the large percentage of futsal players demonstrating limited HF_{KE} (≈47%) and/or ADF_{KF} (35%) ROMs may be based on the demands of the game of futsal that requires players to perform several repeated high intensity movements such as sudden acceleration and deceleration, rapid changes of directions, kicking and tackling (Naser et al., 2017). These movements impose strong concentric and eccentric loads on the hip flexors and ankle dorsiflexion muscles (posterior kinetic chain) at shortened contracted positions (Orchard, 2012; Sun et al., 2015). When these actions are repeated several times during training sessions and matches, they have the potential to generate muscle damage that without the proper recovery and protective measures, might induce impairments in the mechanical and neural properties of the muscle-tendon units, including a reduction in their normal ROMs (Fridén and Lieber, 2001).

The findings of this study also show that, and unlike the between-subject factors player position and competitive level, there was a significant main effect (BF_{10} > 10 [at least a strong evidence in favor of H_1]) for the factor sex on the ROM profile of the futsal players tested whereby females presented higher hip and knee ROM average values than male players. However, it should be noted that for both males and females, all ROM average values (except for the HF_{KE} ROM values [74.1 ± 9.7°] documented for the males that were cataloged as limited [<80°]) were categorized as normal or non-limited. On the other hand, the comprehensive analysis conducted in this study also revealed that more than 20% of male and female players displayed restrictions in their HF_{KE} and ADF_{KF} ROM values. When potential sex-related differences in the proportion of players displaying limited HF_{KE} and ADF_{KF} ROM values were explored, only statistically significant differences were observed in favor of the males for the HF_{KE} ROM (72% [males] vs. 21% [females]). In practical terms, approximately 3 out of 4 diagnosed cases of limited HF_{KE} ROM found in futsal players may be expected to be males. The fact that females presented lower volume of futsal practice per week than males (8.4 h vs. 10.8 h) alongside the larger number of high intensity movements that males perform during matches in comparison with females (Beato et al., 2017; Naser et al., 2017; Serrano et al., 2020) may have contributed to these sex-related differences on the lower extremities ROM profile of the futsal players. Furthermore, unlike the monoarticular ankle dorsiflexion muscles (i.e., soleus and gastrocnemius), the biarticular nature of the hip flexor muscles (i.e., hamstrings) foster them to be repeatedly subjected to the high loading forces generated during most of the futsal-specific movements and this together with the just-mentioned higher exposure to futsal play observed in males as opposed to female players may explain the sex-related differences in the proportion of players with limited HF_{KE} and the absence of them in the ADF_{KF} ROM. Although the current evidence does not allow to make strong claims with regard to the potential effects that limited ROMs may elicit on injury risk, the significant proportion of male futsal players exhibiting limited HF_{KE} ROMs (72%) may help elucidate the reasons why they show a high predisposition to suffer hip flexor muscles strains. For this specific HF_{KE} ROM, the results also report that futsal teams engaged in the first division presented a lower proportion of players with limited values than their counterparts playing in the second division (27% vs. 61%). It is likely that the differences in terms of professionalism (e.g., number of medical and performance staff members, available testing, and training equipment), match physical demands and training status of players between futsal's first and second divisions may justify why the proportion of players showing limited HF_{KE} ROM was lower in teams engaged in the first division than in the second division.

Despite having been considered as an asymmetrical sport (Barbieri et al., 2015), the results of the current study along with the findings of Cejudo et al. (2014), describe non-significant bilateral differences (≥8°) between the dominant and non-dominant lower extremities joints ROM average values in futsal players (independent of player position, competitive level and sex). However, by calculating the number of players with bilateral differences (≥8°) in any hip, knee and ankle ROM measure, the current study found that approximately 20% of futsal players (independent of the player position, competitive level and sex) were identified for HA, HIR, HER, and KF ROMs. There was not a clear pattern in the bilateral differences for the HA, HER, and HIR ROMs so that a similar number of players reported greater values (≥8°) in the dominant and non-dominant limb. Therefore, these bilateral differences may not be attributed to the asymmetrical futsal-specific technical gestures (e.g., kicking and controlling the ball, jumping and turning) that are repeatedly performed during training sessions and matched using mainly the dominant limb. Although a well-founded explanation for this findings has not been found, it might be suggested that these relatively low percentage values of players showing non-patterned bilateral asymmetries (i.e., they are not consistently in favor of the same leg) for the HA, HER, and HIR ROMs may reflect different functional adaptations generated by daily life activities usually performed by players or even an expression of the expected (natural) inter-individual differences attributed to biological (normally distributed) measures (including ROM) as part of being human (Afonso et al., 2020). On the contrary, the bilateral differences for KF ROM reported were mostly in favor of the dominant limb (27 out of 35 cases). A plausible explanation for the KF ROM bilateral differences in favor of the dominant limb identified in this study may be based on the fact that the backswing phase of kicking the ball may reflect in some cases a dynamic stretching for the knee extensor muscles (i.e., quadriceps), which may increase the KF ROM (López-Valenciano et al., 2019). The inter-group analysis revealed that the number of female players showing bilateral differences ≥ 8° in HIR and KF ROMs was approximately double that in males (18% [males] vs. 39% [females] and 18% [males] vs. 33% [females] for HIR and KF ROMs, respectively). Knee ligament injuries often have some long-lasting residual effects and restrictions in HIR and KF ROMs of the injured limb (anecdotical evidence from the authors' extensive experience in team sports injury prevention and rehabilitation). As a higher incidence of knee ligament injury has been documented in female futsal players then it may be a plausible argument to justify why they presented two-fold more positive cases of significant bilateral differences in the HIR and KF ROMs (Ruiz-Pérez et al., 2021).

Finally, some limitations of this study should be acknowledged. The age distribution of participants was relatively narrow and the goalkeepers' sample size was small. Moreover, the use of different testing methodologies (i.e., active ROMs) makes comparisons difficult. Likewise, another limitation of this study relies on the fact that only ROM assessments were carried out and hence, it is not possible to determine whether the same bilateral differences could be found in other physical performance tests (e.g., single-leg vertical countermovement jump test and Y-Balance test). The fact that the all the pre-season ROM assessments were not conducted in the same year (due to time and technical constrains) but in four different ones may be also considered a limitation as it cannot be assumed that all pre-seasons presented similar characteristics (e.g., length [weeks], training congestion), which might have had an effect on players neuromuscular properties at the testing timepoint. For females, the phase of their menstrual cycle during testing was not recorded and this may have potentially influenced their ROM scores as fluctuating concentrations of estrogen throughout the menstrual cycle affect musculotendinous stiffness (Eiling et al., 2007; Bell et al., 2009) and joint laxity (Romani et al., 2003).

The lower extremities ROM assessment was only carried out at the end of the pre-season phase. Thus, potential changes in hip, knee and ankle ROMs over the course of the in-season phase were not monitored. In this sense, previous study analyzing changes in ADF_{KF} and hip (HIR and HER) ROMs over the course of a competitive season for professional male football (Moreno-Pérez et al., 2020) and baseball (Camp et al., 2018; Chan et al., 2020) players, respectively, reported statistically significant ($p < 0.05$) decreases in ADF_{KF} and HER ROMs from pre-season to post-season. Although these documented changes in ADF_{KF} and HER ROMs were defined as statistically significant, their magnitudes (approximately 3° and 6° for ADF_{KF} and HER, respectively) may be considered as not relevant from a clinical standpoint as they did not exceed the value of 1.5 times (80–90% of certainty) the magnitudes of the standard error of the measurement (SEM) reported in previously published reliability studies (Gómez-Jiménez et al., 2015; Gradoz et al., 2018).

PRACTICAL APPLICATIONS

The findings of this study reveal the existence of large proportions of males (72%) and players from teams engaged in the second division (61%) displaying limited HF_{KE} ROMs. Moreover, around 35% of all players showed restricted ADF_{KF} ROMs. The results of this study also indicate no significant differences in the ROM for the hip, knee and ankle joints between outfield players and goalkeepers. Likewise, it has been identified a large total number of players with bilateral differences $\geq 8°$ in HA, HIR, HER and KF ROMs. The number of females with bilateral asymmetries in HIR (18% [males] vs. 39% [females]) and KF (18% [males] vs. 33% [females]) is two time greater than in male players. The potential implications that these restricted HF_{KE} and AD_{FKF} ROMs and bilateral asymmetries in HA, HIR, HER, and KF ROMs caused by the practice of futsal may have on the physical performance and injury risk of the players warrant future research.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Órgano Evaluador de Proyectos, Universidad Miguel Hernández de Elche approved the study (DPS.FAR.02.14). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

FA was supported by a Ramón y Cajal postdoctoral fellowship (RYC2019-028383-I) funded by the Spanish Ministry of Science and Innovation, the State Research Agency (AEI), and the European Regional Development Fund (ERDF). This study is part of the project entitled "Artificial intelligence for pre-participation screening and exercise prescription for sport and health purposes" (code: 35075). This study was conducted during the stay at the School of Sport and Exercise at the University of Gloucestershire (United Kingdom) from 25/11/2019 to 29/01/2020 (Antonio Cejudo).

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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.

frontiers in Psychology

ORIGINAL RESEARCH
published: 11 August 2021
doi: 10.3389/fpsyg.2021.698622

Relationship Between Heart Rate, Oxygen Consumption, and Energy Expenditure in Futsal

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OPEN ACCESS

Edited by:
Miguel-Angel Gomez-Ruano, Polytechnic University of Madrid, Spain

Reviewed by:
Corrado Lupo, University of Turin, Italy
Sadegh Amani-Shalamzari, Kharazmi University, Iran

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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *21 April 2021*
Accepted: *21 June 2021*
Published: *11 August 2021*

Citation:
Silva HS, Nakamura FY, Papoti M, da Silva AS and Dos-Santos JW (2021) Relationship Between Heart Rate, Oxygen Consumption, and Energy Expenditure in Futsal. Front. Psychol. 12:698622. doi: 10.3389/fpsyg.2021.698622

The primary aim of this study was to compare the measured oxygen consumption (Measured-VO_2) in a simulated futsal game (S-Game) with the estimated oxygen consumption (Estimated-VO_2) through a regression equation between heart rate (HR) and oxygen consumption (VO_2) (HR-VO_2) in treadmill running, and a secondary aim was to calculate the total energy expenditure (EE) in S-Game. Ten professional players (22.20 ± 3.22 years) were evaluated. HR-VO_2 was determined individually in the continuous test on the treadmill ($Cont_{Test}$). The Measured-VO_2 in S-Game was compared with the Estimated-VO_2 in the $Cont_{Test}$. Alactic and lactic pathways were estimated by VO_2. The Estimated-VO_2 presented no statistically significant difference with the Measured-VO_2, using the paired *t*-test ($p = 0.38$). However, the correlation between Estimated- and Measured-VO_2 was very weak ($r = -0.05$), and it presented poor agreement (concordance correlation coefficient = −0.04). In addition, a Bland–Altman plot presented bias of −2.8 ml/kg/min and individual difference as large as 19 ml/kg/min. The HR-VO_2 determined by the $Cont_{Test}$ was not a good individual predictor of VO_2. The high intensity and intermittent nature of the futsal game possibly caused dissociation in the HR-VO_2 relationship. $Cont_{Test}$ is not recommended for estimating VO_2 and calculating individual EE in the futsal game. This is recommended only for the group mean. The total EE in S-Game was 13.10 ± 1.25 kcal.min^{-1} (10.81 ± 1.57 metabolic equivalents). The contributions from the metabolic pathways were as follows: aerobic (93%), alactic (5%), and lactic (2%).

Keywords: energy cost, metabolic equivalent, metabolic pathway, team sport, futsal match

INTRODUCTION

The linearity of the relationship between heart rate (HR) and oxygen consumption (VO_2) (HR-VO_2) is observed in progressive continuous exercise (Achten and Jeukendrup, 2003). From the regression equation obtained in treadmill running, it is possible to estimate VO_2 in team sports (Esposito et al., 2004; Castagna et al., 2007) and, consequently, the energy expenditure (EE) (Rodrigues et al., 2011; Makaje et al., 2012; Beato et al., 2016).

However, the thermal and emotional stress and the dehydration of the competition can elevate the HR without affecting the VO_2, changing the linearity of the HR-VO_2 (Esposito et al., 2004; Bangsbo et al., 2006), and inducing an estimation error (Achten and Jeukendrup, 2003; Buchheit et al., 2009). Despite that, HR-VO_2 has been accepted and proposed to estimate VO_2 in intermittent sports, such as soccer (Esposito et al., 2004) and futsal (Castagna et al., 2007). However, Buchheit et al. (2009) do not recommend the use of HR-VO_2 to estimate VO_2 in the handball game, since the estimated VO_2 was lower than the VO_2 measured in the game.

Concerning futsal, a team sport characterized by the intermittent actions of high intensity, accelerations, decelerations, and changes of direction (Makaje et al., 2012), the average intensity of game resulting in 90% maximum HR (Castagna et al., 2009), and blood lactate ([La^-]) can reach 8.3 mmol/L (Dos-Santos et al., 2020), the HR-VO_2 to predict game-specific VO_2 is still not clear. In addition, HR-VO_2 estimates only EE from the aerobic pathway, without considering the lactic and alactic anaerobic pathways. The contribution of the alactic anaerobic pathway from adenosine triphosphate–creatine phosphate (ATP–CP) can be made by calculating the fast component of excess postexercise oxygen consumption (EPOC) (Margaria et al., 1933; Beneke et al., 2002; Bertuzzi et al., 2007), while the EE of the lactic anaerobic pathway can be estimated through the O_2 equivalent for [La^-] (Di Prampero and Ferretti, 1999). These two procedures have been adopted to estimate EE from the anaerobic pathways and to calculate total EE in different sports, such as in tae kwon do, climbing, rowing, and table tennis (Bertuzzi et al., 2007; de Campos Mello et al., 2009; Campos et al., 2012; Zagatto et al., 2016). However, EE from the aerobic pathway has not yet been used in the futsal game.

To our knowledge, there are as yet no studies investigating total EE in futsal, considering the three energetic pathways. Knowing the total EE allows better planning of diet and training. Thus, the primary objective of this study was to compare measured oxygen consumption (Measured-VO_2) in a simulated futsal game (S-Game) with the estimated oxygen consumption (Estimated-VO_2) through a regression equation between HR and VO_2 obtained in the continuous test on the treadmill ($Cont_{Test}$), and the secondary objective was to determine the total EE in S-Game. Considering the intermittent characteristic and the high intensity of the futsal game, it is expected that the VO_2 estimated through the regression equation between HR and VO_2 in the continuous test does not present good agreement with the VO_2 measured in the game. We hypothesized that the Estimated-VO_2 would not correspond to the Measured-VO_2 in S-Game.

MATERIALS AND METHODS

Subjects

Ten professional futsal players of a team participated in the study (22.2 ± 3.2 years; 178 ± 6 cm; 70.2 ± 9.7 kg and 11.8 ± 4.5% of fat), all of them with a minimum experience of 5 years in futsal training and competition, i.e., daily training in two periods (3–4 h/day), 5–6 days/week. Players belonged to a team that played in the main competition in the State of São Paulo, Brazil, the Paulista League. Participants were previously informed of all procedures and signed a consent form. The design and protocol of the study conformed to the ethical standards established in the Declaration of Helsinki (2013) and was approved by the Ethics Committee of the University, according to the national laws (CAAE: 41515915.5.0000.5398).

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The characteristics of the subjects were made by measuring height [using stadiometer (Welmy, Santa Bárbara do Oeste, São Paulo, Brazil)], mass, and body composition [using the dual-energy X-ray absorptiometry (DXA), Discovery Wi, Hologic, Bedford, MA, USA], adopting all the procedures of the manufacturer. A $Cont_{Test}$ was performed to obtain a linear regression equation ($y = ax + b$) and to calculate the Estimated-VO_2 in S-Game. In addition, HR-VO_2 was determined for each player in S-Game to analyze the slope of the linear equation and to compare it with that generated by $Cont_{Test}$. The Estimated-VO_2 was compared with the Measured-VO_2. The EE corresponding to each metabolic pathway (i.e., aerobic, alactic, and lactic anaerobic) was determined in S-Game. All tests were performed in random order between 9:00 a.m. and 12:00 p.m., without any vigorous physical exertion in the previous 24 h. At least a 48-h interval was interspersed in the $Cont_{Test}$ and S-Game for each player. The ambient temperature in all assessments varied between 28 and 32°C.

Continuous Test on the Treadmill ($Cont_{Test}$) and Simulated Futsal Game (S-Game)

The $Cont_{Test}$ was performed on a treadmill (Inbramed ATL, Porto Alegre, Brazil) with a slope of 1%, an initial velocity of 8.0 km/h, and an increase of 1.0 km/h at each minute, until exhaustion (Kuipers et al., 2003). The VO_{2max} was determined according to the criteria proposed by Howley et al. (1995). Players from the same team participated in the S-Game, which consisted of four outfield players and the goalkeeper, randomly selected, following the rules of futsal on the court measuring 40 × 20 m. The data collection time for each player in S-Game was 10 min, since substitutions in futsal are unlimited, and in official matches, the players stay an average of 10 min playing effectively on the court before being substituted (Castagna et al., 2009; Makaje et al., 2012). In addition, a 10-min effort period has been used in the studies with S-Game (Castagna et al., 2009; Milioni et al., 2016). Considering the time taken for the data collection, the use of a portable gas analyzer, and the availability of players by the technical committee of the team, the data collection of S-Game was performed with one player in each 10-min S-Game, on separated days by more than 48 h. The physical coach of the team refereed the games, and the head coach was present to guide and encourage the players. Before the S-Game, a blood sample (i.e., 25 µl of the earlobe) was taken from the players for the analysis of [La^-] at rest, and after blood collection, VO_2 was measured at rest for 10 min in a sitting position. Subsequently, the players performed a standardized 10-min warm-up (e.g., jogging–running free = 2 min, dynamic exercises = 3 min, and exercises with ball = 5 min), and during the 10-min S-Game, the VO_2 and HR were also measured. After the S-Game, VO_2 was

TABLE 1 | Comparison between the measured oxygen consumption (Measured-VO_2) in simulated futsal game (S-Game) and the estimated oxygen consumption (Estimated-VO_2) estimated by the HR-VO_2 regression equation from the continuous treadmill test.

	Measured-VO_2 (95% CI)	Estimated-VO_2 (95% CI)	*p*-value	Cohen's ES (*d*)	Pearson's (*r*)	Lin's (CCC)
VO_2 (mL.Kg.min−1)	35.21 ± 4.90 (32.71–38.72)	38.04 ± 8.13 (32.23–43.86)	0.38	0.43 (small)	−0.05 (very weak)	−0.04 (poor)

Values expressed as mean ± SD. HR, Heart rate; VO_2, oxygen consumption; ES, effect size; 95% CI lower and upper limits.

measured at rest during 10 min for the EPOC examination, and the blood samples were taken at 1, 3, 5, and 7 min to determine $[La^-]$ peak.

Measurements of the Physiological Parameters

In all procedures, the HR was recorded for each second. The maximum HR (HR_{max}) was considered the highest value in $Cont_{Test}$. The gas analyses were performed with the K4 b2 device (Cosmed Srl, Rome, Italy), with all calibrations and other procedures recommended by the manufacturer. The respiratory variables were smoothed every five points and interpolated every second to reduce the artifacts (Özyener et al., 2001). Estimated-VO_2 was calculated by HR-VO_2 for each player in $Cont_{Test}$, obtaining a linear regression equation ($y = ax + b$), and considering the mean of HR (HR_{mean}) obtained in S-Game. Measured-VO_2 was calculated by the area of VO_2 by each HR record, disregarding the VO_2 at rest, to determine EE only during futsal game.

Samples of $[La^-]$ were collected in capillary tubes (i.e., 50 µl of 1% sodium fluoride) and analyzed on YSI 2300 SPORTS (Yellow Springs Instruments, Yellow Springs, OH, USA). The energy demand of the aerobic (W_{AER}), alactic anaerobic (W_{PCR}), and lactic anaerobic ($W_{[La^-]}$) metabolism was estimated as follows: W_{AER} = difference between the area of VO_2 during the S-Game (i.e., calculated by the trapezoidal integration method) of the VO_2 at rest (i.e., calculated by the product between the VO_2 at rest and the total duration of the game) (Beneke et al., 2002; Bertuzzi et al., 2007; Campos et al., 2012); W_{PCR} = fast component of EPOC measured after S-Game, i.e., calculated by the product between the amplitude and tau (τ) obtained by means of the bi-exponential adjustment of VO_2 (Beneke et al., 2002; Bertuzzi et al., 2010); and $W_{[La^-]}$ = difference between the peak lactate of the S-Game and at rest (Δ $[La^-]$), considering the equivalent energy of 3 ml of O_2·per kg for each 1 mmol/L of $[La^-]$ (Di Prampero and Ferretti, 1999). Thus, the total EE (i.e., $W_{AER} + W_{PCR} + W_{[La^-]}$) was expressed in several ways to facilitate its application, considering the equivalent for O_2 ml/kg/min in kilocalories (kcal) and metabolic equivalent (MET) (Bertuzzi et al., 2007; McArdle et al., 2014).

Statistical Analysis

The Shapiro–Wilk test was used to verify the normality of the data. After confirming the normality of the data, the paired *t*-test was applied. The 95% CI was determined, and the effect size (ES) was calculated by using Cohen's *d* (Cohen, 1988), considering ES: <0.19 trivial, 0.20–0.49 small, 0.50–0.79 moderate, and >0.80 large. The Pearson's correlation was determined and classified according to the values of *r* as follows: very weak (0.0–0.2), weak (0.2–0.4), moderate (0.4–0.7), strong (0.7–0.9), and very strong (0.9–1.0) (Glickman and Rowntree, 1982). The Bland–Altman analysis was used to verify the agreement between Measured-VO_2 and Estimated-VO_2, as well as the Lin's concordance correlation coefficient (CCC), following the scale for strength of agreement: poor (<0.90), moderate (0.90–0.95), substantial (0.95–0.99), and almost perfect (>0.99) (Lin, 1989). The level of significance was set at 5%. The calculations were performed using the following statistical programs: IBM SPSS Statistics software for Windows, version 22.0 (IBM Corp, Armonk, NY, USA), and MedCalc 9.2 (MedCalc Software bv, Ostend, Belgium).

RESULTS

The values of Measured-VO_2 and Estimated-VO_2 presented no significant difference (**Table 1**). Considering only the W_{AER}, the EE also did not differ statistically (i.e., measured = 12.19 ± 1.09 and estimated = 13.32 ± 3.17). However, the correlations demonstrated that Estimated-VO_2 did not correspond to Measured-VO_2 individually (**Table 1**). In the Bland–Altman analysis (**Figure 1**), it is possible to observe the data scatter and the low agreement between the Estimated-VO_2 and Measured-VO_2, a bias of −2.8 ml/kg/min, and the limits of agreement varying in 19 ml/kg/min. When comparing the slope averages of the linear regression equation generated by the HR-VO_2 in the $Cont_{Test}$ (0.48 ± 0.12) and S-Game (0.28 ± 0.21), significant differences were observed between the slopes ($p = 0.007$). The correlation coefficients of the HR-VO_2 in $Cont_{Test}$, $r = 0.95 \pm 0.03$, and in S-Game, $r = 0.61 \pm 0.27$, presented significant difference ($p = 0.003$), and the explication coefficients were $r^2 = 0.91 \pm 0.05$ and $r^2 = 0.44 \pm 0.29$, respectively. The HR-VO_2 of a player in the two situations (i.e., $Cont_{Test}$ and S-Game) allows visualizing these differences (**Figure 2**). The S-Game presented a high-intensity level as expected for futsal as follows: HR_{mean} = 163 ± 7 bpm, corresponding to HR_{max} = 90 ± 4%. The HR_{max} in S-Game was 188 ± 11 bpm, whereas it was 182 ± 7 bpm in $Cont_{Test}$. $[La^-]$ peak after S-Game was 3.57 ± 1.34 mmol/L.

Table 2 shows the total EE and the proportions of the contribution of each energy pathway in the S-Game, disregarding the resting values of each individual. The anaerobic EE represented 7% of the total contribution in S-Game.

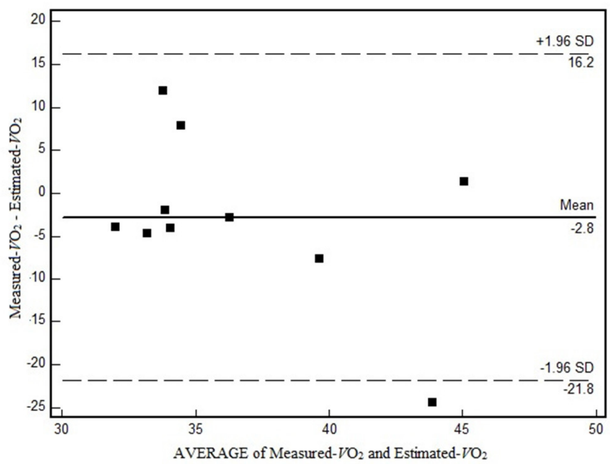

FIGURE 1 | The Bland–Altman analysis for oxygen consumption (VO_2 ml/kg/min) between Measured-VO_2 and Estimated-VO_2.

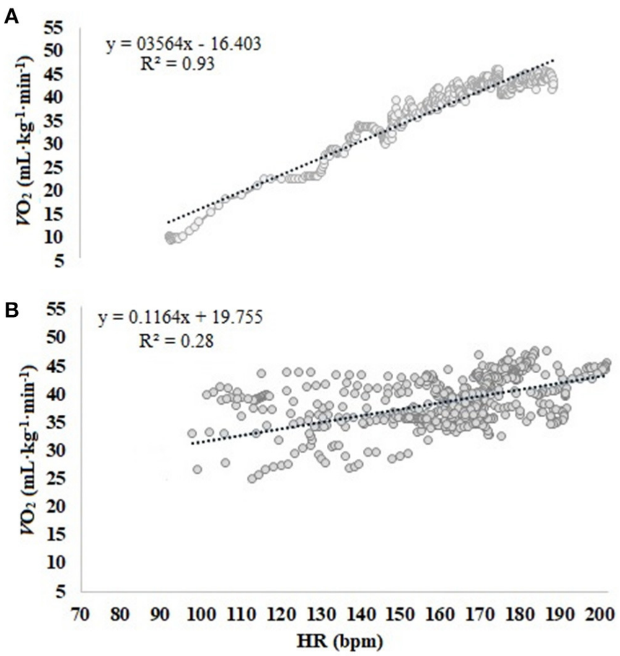

FIGURE 2 | Relationship between heart rate (HR, bpm) and oxygen consumption (VO_2, ml/kg/min) of an athlete, during the tests: **(A)** continuous treadmill test ($Cont_{Test}$) and **(B)** simulated futsal game (S-Game).

DISCUSSION

The primary objective of this study was to compare the Measured-VO_2 with the Estimated-VO_2 in futsal, through the regression equations generated from the HR-VO_2 obtained in the $Cont_{Test}$. Although the Estimated-VO_2 presented no significant difference with the Measured-VO_2, they presented a very weak correlation and poor agreement (**Table 1**). It could be remarked that, according to this main finding, the HR-VO_2 determined by the $Cont_{Test}$ was not a good individual predictor of VO_2. Considering the secondary objective, the aerobic energy demand in S-Game was 93%, anaerobic alactic, 5%, and anaerobic lactic, 2%.

TABLE 2 | The energy expenditure of the aerobic (W_{AER}), alactic anaerobic (W_{PCR}), and lactic anaerobic ($W_{[La^-]}$) metabolism in S-Game.

	W_{AER}	W_{PCR}	$W_{[La^-]}$	Total
VO_2 (ml/kg/min)	35.21 ± 4.90	1.92 ± 0.83	0.70 ± 0.39	37.83 ± 5.49
VO_2 (L/min)	2.44 ± 0.22	0.13 ± 0.05	0.05 ± 0.03	2.62 ± 0.25
EE (kcal.min^{-1})	12.19 ± 1.09	0.66 ± 0.25	0.25 ± 0.14	13.10 ± 1.25
EE (METs)	10.06 ± 1.40	0.55 ± 0.24	0.20 ± 0.11	10.81 ± 1.57
Percentage (%)	93.15 ± 2.29	4.99 ± 1.70	1.87 ± 1.04	100.00 ± 0.00

VO_2, oxygen consumption; EE, energy expenditure; METs, metabolic equivalents.

There was no significant difference (using the paired *t*-test) between the Measured-VO_2 and the Estimated-VO_2, indicating that our hypothesis should be refuted (i.e., HR-VO_2 of the $Cont_{Test}$ would not be a good game-related VO_2 predictor). However, the correlation and concordance tests evidenced the low predictive capacity of VO_2 by HR-VO_2 from a test on the treadmill (i.e., $Cont_{Test}$) for estimating VO_2 in futsal game. In addition, the correlation coefficients from $Cont_{Test}$ and S-Game were different, $r = 0.95$ and $r = 0.61$, respectively. In futsal recreational game with high school students, the estimated and measured VO_2 in futsal game did not differ either (Castagna et al., 2007). Although the authors pointed out the validity of the estimation of VO_2 from the regression equation in treadmill running, they stated that HR might have a less predictive capacity of real aerobic involvement during intermittent activities compared with continuous exercise. Therefore, they recommended that the HR-VO_2 be only used for groups and not individually since the correlation coefficient of the HR-VO_2 presented a statistical difference ($p < 0.001$) between the futsal game ($r = 0.83$) and the treadmill running ($r = 0.96$). Those authors assumed that other occasional activities, such as high-speed running or isometric muscle actions, may explain some differences between HR and VO_2 in intermittent exercise vs. continuous exercise. In addition, the heat and stress factors of the game can influence the dissociation of the response of HR-VO_2 (Achten and Jeukendrup, 2003). Another interesting result that must be taken into account when analyzing the HR-VO_2 is the intensity. Notably, in this study, the average HR was $HR_{max} = 90\%$, similar to the official games (Barbero-Alvarez et al., 2008), while in the recreational game with high school students, the average HR was $HR_{max} = 83\%$ (Castagna et al., 2007), resulting in a weaker correlation in the HR-VO_2 when the game is more intense ($r = 0.61$ vs. 0.83, respectively). However, the HR-VO_2 from the treadmill test has been used to estimate the VO_2 in team sports, such as soccer.

In soccer, Hoff et al. (2002) indicated HR as a valid indicator of VO_2 in a 5 vs. 5 small-sided game and in a dribbling field test. However, the authors used average values for the correlation analysis between HR and VO_2 and did not compare the correlation coefficients between the different situations. Esposito et al. (2004) did not observe a significant difference between the VO_2 measured in the specific field test to soccer and that estimated by the equation in the treadmill test, recommending that the HR-VO_2 regression equation obtained on the treadmill is valid to calculate VO_2. In this study, Measured-VO_2 and Estimated-VO_2 by HR-VO_2 were not different either. However, the results of the Estimated-VO_2 by HR-VO_2 did not present concordance. We compared the Estimated-VO_2 by HR-VO_2 with the Measured-VO_2 in S-Game, which is more specific than a field test, as used in studies with soccer (Hoff et al., 2002; Esposito et al., 2004). Although in the study by Hoff et al. (2002), the subjects were also evaluated in a 5 vs. 5 small-sided soccer game, and the calculation of the individual VO_2 using the HR-VO_2 equation from the treadmill was not carried out (Hoff et al., 2002). Besides, futsal is more intense than soccer (Barbero-Alvarez et al., 2008), since the actions are carried out in a smaller space and with more frequent changes of direction. The intermittent characteristic and the high intensity of the futsal game certainly contributed to the difference observed between HR and VO_2 of S-Game and one obtained in continuous exercise test (**Figure 2**). Considering different methods used in the studies, and although some authors recommended the use of the HR-VO_2 in soccer to estimate the VO_2, the methods applied in this study demonstrated that the individual HR-VO_2 in continuous exercise in treadmill can estimate different VO_2 values of the Measured-VO_2 in futsal game for each player.

Contrary to the studies cited above, in a study with handball players, Buchheit et al. (2009) did not recommend the use of HR-VO_2 to estimate VO_2. The authors found a good HR-VO_2 for the treadmill test of goodness of fit ($r^2 = 0.96$) but a moderate HR-VO_2 for the handball game and intermittent exercise ($r^2 = 0.63$ and $r^2 = 0.58$, respectively). Moreover, VO_2 estimated from the HR-VO_2 in the treadmill test was lower than the VO_2 measured in the handball game ($p = 0.03$). It was also possible to observe a large difference between VO_2 measured in a handball game and that estimated from the intermittent exercise, 8.7 and 11.6 ml/kg/min, respectively. In handball, there are accelerations, decelerations, jumps, changes of direction, and actions of the upper limbs that increase the active muscle mass, which differs a lot from running on the treadmill.

The very weak correlation between Estimated-VO_2 and Measured-VO_2 ($r = -0.05$), ES estimated by Cohen's d, classified as small (0.4), and the CCC as poor (CCC $= -0.04$) corroborate results observed in handball (Buchheit et al., 2009), making clear the difference between the characteristics of the continuous exercise with the intermittent sports. In our results (**Figure 2**), it is possible to observe the difference in the dispersion of the data between the two exercise situations evaluated. The difference found between the slopes of the regression lines, $\text{Cont}_{\text{Test}}$ (0.48 $\pm$ 0.12) and S-Game (0.28 $\pm$ 0.21) ($p = 0.007$), is an indication that the HR-VO_2 responded differently in both $\text{Cont}_{\text{Test}}$ and S-Game. A Bland–Altman plot in this study presented a bias of -2.8 ml/kg/min and individual difference as large as 19 ml/kg/min. The result of bias was similar to those from another study on futsal, -2.2 ml/kg/min, while the limit of agreement in this study was higher than 8 ml/kg/min (Castagna et al., 2007), however, the higher limit of agreement, in comparison with the results of Castagna et al. (2007), 8 ml/kg/min. The higher intensity of the S-Game in this study (90% HR_{max}) compared with 83% HR_{max} (Castagna et al., 2007) can explain the difference between the two studies. As a result, the higher the intensity of the intermittent exercise, the greater the dissociation in HR-VO_2, reinforcing the data from Balsom et al. (1992), which suggested that HR increased disproportionately to the VO_2 after sprinting activities.

The low correlation and the agreement between Measured-VO_2 and Estimated-VO_2 of this study indicate that the equations of HR-VO_2 generated from the continuous test are not good for estimating VO_2 individually, and although there is no difference to estimate the "rough" VO_2 of the group, it is not recommended to plan diets or the training load from this calculation, due to the biological individuality of each athlete and unpredictable situations in the game, which influence the HR-VO_2.

The use of HR-VO_2 in the estimation of VO_2 in team sports should be viewed with caution since the literature presents contradictory results. Studies with soccer (Esposito et al., 2004) and futsal (Castagna et al., 2007) indicated the validity of HR-VO_2, whereas in handball (Buchheit et al., 2009) and in this study with futsal, HR-VO_2 was not valid for the estimation of VO_2 by HR from the continuous progressive test. Another interesting fact in this study is that the comparison between Measured-VO_2 and Estimated-VO_2 from HR-VO_2 was made by calculating the integral area of VO_2 over the time during S-Game since for each recorded HR there are different VO_2 values. In other studies, VO_2 was estimated using the HR_{mean} of the exercise (Esposito et al., 2004; Castagna et al., 2007; Makaje et al., 2012), which can be a bias of those studies.

In addition to HR-VO_2 and the aerobic EE, we also calculated the total EE (i.e., $W_{AER} + W_{PCR} + W_{[La^-]}$). The same method for calculating the total EE has been used in other sports, as tae kwon do (Campos et al., 2012), climbing (Bertuzzi et al., 2007), rowing (de Campos Mello et al., 2009), and table tennis (Zagatto et al., 2016). In all these studies about EE and as also verified in this study, the calculated value of the lactic anaerobic pathway has been the lowest value, which can be a characteristic of the sports evaluated or a limitation of the method. Certainly, the measurement of anaerobic EE is more difficult than aerobic EE, and it has limitations. For example, in an incremental exercise, it is recommended that stages between 3 and 6 min be used to obtain precise $[La^-]$ measurements (Bentley et al., 2007), ensuring the efflux of muscle lactate to not underestimate the $[La^-]$ value. In contrast, if after 5–6 min the lactate efflux from the muscle into the blood is guaranteed, the measurement taken in a time above this can lead to loss of information. Completing this idea, Stølen et al. (2005) pointed out that, in soccer, the $[La^-]$ measure depends largely on the activity pattern in 5 min preceding the sample collection, since $[La^-]$ results from the production/removal ratio, which is influenced by the value of the lactate produced, activity during the recovery period, and aerobic capacity. In addition, for the 5 vs. 5 small-sided games in soccer, Hoff et al. (2002) indicated

4 min of play to reach at least 3 min at high intensity. Thus, we suggested that in future studies, mainly on futsal, blood samples be taken with VO_2 at 3, 4, and/or 5 min to verify if the length of the playing period can influence the calculation of the lactic EE per minute, since the intensity of the futsal game is higher than in soccer and HR average is 90% HR_{max} (Barbero-Alvarez et al., 2008), with less variation in HR (i.e., coefficient of variation = 7%) during the game (Dos-Santos et al., 2020).

The alactic EE also has limitations and can be underestimated due to the intermittent character of the futsal game with changes between high-intensity activity and the activities of lower intensity and pauses, which reduce the VO_2. However, the VO_2 recovery of those VO_2 reduction periods is not considered or measured during the game, limiting the exact calculation of the W_{PCR}.

The EE in the S-Game was determined, disregarding the resting VO_2, to account only the activity EE of futsal. The total EE measured was 13.10 ± 1.25 kcal.min^{-1}, W_{AER} = 93%, W_{PCR} = 5%, and $W_{[La^-]}$ = 2%. The aerobic EE measured was 12.19 ± 1.09 kcal.min^{-1}. In futsal game with recreational players, Beato et al. (2016) found 634 ± 92 kcal for 52 ± 2 min, (≈12.19 kcal.min^{-1}), and Makaje et al. (2012) found 595 ± 50 kcal (≈14.81 kcal.min^{-1}) for elite players and 543 ± 67 kcal (≈13.57 kcal.min^{-1}) for amateurs. Both studies were estimated by HR-VO_2 relation, and they were close to the values evidenced in this study. However, in official games, Rodrigues et al. (2011) found higher values than the ones in the present study and the other studies, 18 kcal.min^{-1}. In this case, the EE is expected to be higher in official games, or the value might have been overestimated, reinforcing that caution is needed in estimating EE from HR-VO_2.

Considering the EE expressed in METs, the total EE of S-Game was 10.81 METs, which is a higher EE than in other team sports such as soccer (10.0 METs) and basketball (7.0 METs) (Ainsworth et al., 2000). The results expressed in METs of the EE of S-Game reinforce the findings of Barbero-Alvarez et al. (2008), which show that futsal is more intense than soccer, basketball, and handball. Our results can serve as a reference to guide and assist in assessment and prescription programs for weight control and exercise for health.

Although there is a limitation in the determination of the alactic and lactic anaerobic in intermittent exercise, it was possible to add information and to obtain the EE closest to the real one. This is the first study that proposed to investigate the anaerobic EE response and to add information about total EE in futsal. Further studies on total EE in futsal shorter-duration games are needed so that the anaerobic pathways are not thus underestimated. The shorter-duration games supposedly demand greater stress, intensity, heat production, intermittency, and alteration of game activities, i.e., the variables that may interfere with the physiological responses of the players.

CONCLUSION

The HR-VO_2 from the continuous test did not accurately estimate VO_2 in the futsal game. HR-VO_2 is not recommended for estimating VO_2 and calculating individual EE in futsal, since it does not present acceptable agreement and correlation with the Measured-VO_2 in the futsal game. The values estimated by HR-VO_2 approach the average value of the game, which can only be used to estimate the "rough" VO_2 of groups. The S-Game presented the total EE (i.e., $W_{AER} + W_{PCR} + W_{[La^-]}$) of 13.10 ± 1.25 kcal.min^{-1}. In futsal (S-Game), the highest demand came from the aerobic pathway, 93%, from the alactic anaerobic pathway, 5%, and from the lactic anaerobic pathway, 2%.

DATA AVAILABILITY STATEMENT

The original contributions and raw data presented in the study are included in the article, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of School of Science, São Paulo State University (UNESP), Bauru, Brazil, in accordance with local laws and ethical standards established in the Declaration of Helsinki. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

HS and JD-S planed the study. HS contributed to the data collection, statistical analysis, and manuscript writing. AS contributed to the analysis and design. FN and MP have made substantial contributions to conception and design. JD-S, HS, and FN reviewed the manuscript, and JD-S contributed to conception and approval of the final version for publication. All authors have approved the final version of the manuscript.

FUNDING

This study was financially supported by the National Council for Scientific and Technological Development (CNPq, Process: 160137/2014-4) and was also carried out with the support of the Coordination for the Improvement of Higher Education Personnel (CAPES), Brazil (Finance Code 001).

ACKNOWLEDGMENTS

The authors thank the staff of the Department of Physical Education of UNESP, Bauru, the technical committee and players of AA FIB Futsal, and the members of the research group FITES for their support.

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frontiers in Psychology

ORIGINAL RESEARCH
published: 28 January 2022
doi: 10.3389/fpsyg.2021.751030

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Quantification of Respiratory and Muscular Perceived Exertions as Perceived Measures of Internal Loads During Domestic and Overseas Training Camps in Elite Futsal Players

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OPEN ACCESS

Edited by:
*Bruno Travassos,
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Reviewed by:
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Timothy Lathlean,
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Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *31 July 2021*
Accepted: *15 December 2021*
Published: *28 January 2022*

Citation:
Lu Y-X, Clemente FM, Bezerra P, Crowley-McHattan ZJ, Cheng S-C, Chien C-H, Kuo C-D and Chen Y-S (2022) Quantification of Respiratory and Muscular Perceived Exertions as Perceived Measures of Internal Loads During Domestic and Overseas Training Camps in Elite Futsal Players. Front. Psychol. 12:751030. doi: 10.3389/fpsyg.2021.751030

Background: The rating of perceived exertion (RPE) scales with respiratory and muscular illustrations are recognized as simple and practical methods to understand individual psychometric characteristics in breathing and muscle exertion during exercise. However, the implementation of respiratory and muscular RPE to quantify training load in futsal training camps has not been examined. This study investigates respiratory and muscular RPE relationships during domestic training camps (DTC) and overseas training camps (OTC) in an under 20 futsal national team.

Methods: Data collected from eleven field players were used for comparison in this study (age = 18.7 ± 0.7 years, height = 171.9 ± 6.1 cm, body weight = 64.2 ± 8.4 kg). All players reported Borg CR10 RPE (RPE_{CR10}) and 7-scales respiratory RPE ($RPE_{respiration}$) and muscular RPE (RPE_{muscle}) (Dalhousie pictorial scales) after training sessions and matches. Additionally, total distance covered (TD) and training impulse (TRIMP) were used to quantify external and internal loads *via* the Polar Team Pro system. Paired-sample *t*-tests were used to compare the RPE_{CR10}, $RPE_{respiration}$, RPE_{muscle}, TD, and TRIMP between DTC and OTC. Furthermore, linear regression was performed to determine the relationships among all RPE scales, TD, and TRIMP.

Results: The RPE_{CR10} ($p = 0.047$), TD ($p < 0.001$), and TRIMP ($p < 0.001$) showed significant difference between DTC and OTC. Furthermore, linear regression analyses showed significant correlation between $RPE_{respiration}$ and RPE_{muscle} (DTC: $r = 0.857$, $p = 0.006$; OTC: $r = 0.924$, $p < 0.001$), RPE_{CR10} and $RPE_{respiration}$ (DTC: $r = 0.857$,

$p = 0.001$; OTC: $r = 0.863$, $p = 0.001$), and RPE_{CR10} and RPE_{muscle} (DTC: $r = 0.906$, $p < 0.001$; OTC: $r = 0.900$, $p < 0.001$).

Conclusion: Pictorial $RPE_{respiration}$ or RPE_{muscle} can be used as an alternative to quantify perceived measures of internal loads during DTC and OTC in futsal players. Interpretation of perceived measures of training load and cardiac-related responses in association with external training loads during short-term training camps would be useful in further understanding the demands of futsal players' experience in these circumstances.

Keywords: monitoring training loads, training camps, futsal training, Borg CR10, heart rate, total distance covered

INTRODUCTION

The monitoring of training loads is a practical method to evaluate physical adaptation and recovery status during a training period (Bourdon et al., 2017). Methodologies to monitor training loads can be divided into internal and external measures (Impellizzeri et al., 2019). Internal measures of load can be evaluated *via* self-report measures [i.e., rating of perceived exertion (RPE)] or objective measures of physiological response [i.e., heart rate (HR) and blood lactate concentration] (Clemente et al., 2019). Conversely, external load measures that assist in measuring locomotion profiles *via* microelectromechanical systems (e.g., global navigation satellite system, inertial measurement unit, or local positioning system) can be used to evaluate physical impact and physiological strains during training sessions and competitions (Halson, 2014).

Futsal is a high-intensity intermittent and strenuous indoor sports (Barbero-Alvarez et al., 2008) requiring both aerobic and anaerobic energy systems to maintain vigorous physical and mental conditions (Naser et al., 2017). Futsal competitions are incredibly high in intensity and often cause intensive physiological and psychological strains to the players. It has been reported that high-speed running (18.1–25 $km.h^{-1}$) and sprinting (>25 $km.h^{-1}$) account for 22.6% of the total distance covered (TD) during a competitive futsal match. Additionally, field players have average HR responses between 170 and 190 $beats.min^{-1}$ in Liga Nacional de Futbol Sala (around 83% of maximal HR during the match time), representing a high cardiovascular load on players (Barbero-Alvarez et al., 2008). This cardiovascular load results from rapid changes in various activities every 8–9 s (e.g., high-speed running, sprints, change of direction, and lateral and backward activity) during matches (Álvarez et al., 2009).

Much like during match scenarios, monitoring the demands of futsal training is also important to understand the accumulation of the training load imposed on an individual player (Clemente et al., 2020). Among the possible methods of monitoring internal load, the RPE is a simple and practical tool to quantify since it is a valid, low-cost, and reliable method in measuring exercise intensity (Haddad et al., 2017). The RPE is based on psychological perception in response to training and/or exercise stimuli. An 11-points scale version from 0 (no exertion) to 10 (maximal effort), Borg CR10 scale (RPE_{CR10}), is developed to evaluate physiological and psychological perceptions in response to exercise strain in laboratory and field settings (Foster et al., 2001). Subsequently, the RPE_{CR10} in respect to the exercise or training duration was used to quantify internal training load in sports training (Foster et al., 2001). This method has been extensively used in team sports, such as soccer (Impellizzeri et al., 2004; Clemente et al., 2019) and futsal players (Chen et al., 2020; Clemente et al., 2020; Stochi de Oliveira and Borin, 2021) due to convenience and user-friendliness.

The respiratory ($RPE_{respiration}$) and muscular (RPE_{muscle}) perceived exertions are variants of RPE scales. The $RPE_{respiration}$ and RPE_{muscle} primarily focus on the breathing efforts and leg fatigue during exercise, respectively (Pianosi et al., 2014, 2015). The benefit of using both the $RPE_{respiration}$ and RPE_{muscle} scales is that they identify specific characteristics of psychophysiological responses in cardiopulmonary and leg muscle performance. The advantage of using different RPE scales to quantify training load is related to the sensitivity of the measurement. In terms of Dalhousie pictorial scales, seven different illustrations for dyspnea (chest tightness, throat closure, breathing effort, etc.) and perceived leg exertion (light leg, heavy leg, soft leg, etc.) are used to represent different physiological strains in responses to different exercise loads. The validity to use Dalhousie scales to rate respiratory and leg muscle exertions during exercise activity has been reported in pediatric populations, compared to RPE_{CR10} measure.

In terms of specific training sessions, physical demands may activate different sensory feedbacks and physiological constraints in target body systems during the performance. McLaren et al. (2016) previously reported that the sensitivity of $RPE_{respiration}$ was different from RPE_{muscle} during incremental cycling and treadmill running in university soccer players. Furthermore, Wright et al. (2020) recently demonstrated that young female soccer players experienced stronger perceived exertions in breathing and muscular engagement during fitness and resistance training, respectively. However, no difference in respiratory and muscular perception during soccer training sessions and matches has been observed. Wright et al.'s (2020) study implied the different perceptions of sensory sources to specific training types in this population. However, the application of these measures in futsal training lacks sufficient investigation and requires further elucidation.

Futsal training camps include team preparation, player selection, building and developing team tactics and formations, physical and mental preparation, and team squad readiness. In general, domestic training camps (DTC) provide benefits for testing squad members in individual and team performance, periodizing physical and mental preparation, and tactical strategies prior to tournaments (Clemente et al., 2020). Conversely, overseas training camps (OTC) have advantages in creating a simulative environment of official tournaments and thus familiarizing players with the usual intensity of psychophysiological responses during competitions (Lu et al., 2019; Chen et al., 2020). However, a comparative study to examine training loads between DTC and OTC has not been reported elsewhere.

In light of the above, this study compares the different training measures during DTC and OTC in under 20 (U-20) male futsal players, and examines relationships between the RPEs and traing impulse (TRIMP)/TD. It was hypothesized that there would be significant differences in measured variables between DTC and OTC. The secondary hypothesis was that the relationship between perceived exertions and TRIMP/TD would be established during DTC and OTC.

MATERIALS AND METHODS

Participants

Eleven male futsal field players from a national U-20 futsal team voluntarily participated in this study (age = 18.7 ± 0.7 years, height = 171.9 ± 6.1 cm, body weight = 64.2 ± 8.4 kg). All players signed informed consent forms and were familiarized with the procedures in reporting RPE values. This study was approved by the Human Ethics Committee of the University of Taipei (UT-IRB-2018-068) and undertaken in accordance with the Declaration of Helsinki and its later amendment.

Design and Procedure

This was a prospective cohort study to observe the training loads during futsal training camps. The training camps consisted of eight short-term DTC (including 83 training sessions, total training duration = 149.23 h) and three short-term OTC (including 14 training sessions and 11 friendly matches, total training/match duration = 41.87 h). The description of the study period and the individual exposure time to training are presented in **Tables 1**, **2**, respectively. **Figure 1** illustrates the number and types of training sessions during each training camp. The training loads during the training camps were assessed *via* (1) perceived internal load = RPE_{CR10}, $RPE_{respiration}$, RPE_{muscle}; (2) HR-related internal load = TRIMP; and (3) external load = TD. During all training sessions and friendly matches, all players wore microsensors HR monitors on the chest (Polar Team Pro, Polar Electro, Kemple, Finland). The microsensor and chest strap were marked with a unique jersey number throughout the training camps. HR responses and activity profiles were recorded and used to calculate TRIMP and TD for subsequent data processes. For the RPE scales, players reported individual perception of RPE_{CR10}, $RPE_{respiration}$, and RPE_{muscle} responses within 30 min after training sessions or friendly matches (Impellizzeri et al., 2004). The team sports trainer asked the players the following three questions: (1) How hard was your training session? (2) How does your breathing feel? (3) How do your legs feel? Subsequently, session RPE_{CR10} ($sRPE_{CR10}$), session $RPE_{respiration}$ ($sRPE_{respiration}$), and session RPE_{muscle} ($sRPE_{muscle}$) were used to calculate training loads. The sRPE was calculated based on the RPE scales × time of training sessions or matches (Foster et al., 2001).

TABLE 1 | The description of study period.

Training camps	Duration (days)	Interval between the training camp (days)
DTC1	7	–
DTC2	7	44
DTC3	7	14
DTC4	7	21
DTC5	7	12
OTC1	4	8
DTC6	5	83
DTC7	6	10
DTC8	5	16
OTC2	6	9
OTC3	9	43

DTC, domestic training camps; OTC, overseas training camps.

Rating of Perceived Exertion

Each individual's RPE responses were recorded using the Borg CR10 scale and Dalhousie pictorial scale to quantify RPE_{CR10}, $RPE_{respiration}$, and RPE_{muscle}, respectively. The RPE_{CR10} is a brief version of 0–10 points scale, modified from the original Borg RPE (Borg, 1998). The RPE_{CR10} is a visual analog scale that is numerically represented as 0 being "not at all" and 10 being "extremely intense." Additionally, the Dalhousie pictorial scales consisted of seven cartoon pictures to reflect perceived exertion in breathing effort and leg sensation during exercise. The lowest value of 1 represented "very light feeling" and the highest value of 7 represented "extremely intense feeling" (Pianosi et al., 2014, 2015, 2016). In our study, the 7-points Dalhousie pictorial scale was used to assess the respiratory and muscular RPE as it is correlated with respiratory and muscular exertions during exercise in adolescents (median value of Spearman's $r > 0.9$) (Pianosi et al., 2015). Subsequently, all RPE scores were multiplied by the time of training sessions and friendly matches as session RPE values (Foster et al., 2001). The participants were informed of the definition of RPE scales on the first registration day and were afforded the opportunity to practice reporting RPE values during the first DTC.

Training Impulse

Polar microsensors recorded the exercising HR responses during training and matches and were used to calculate TRIMP. The

TABLE 2 | The individual exposure time to training during the training camps.

Player	DTC1 (min)	DTC2 (min)	DTC3 (min)	DTC4 (min)	DTC5 (min)	DTC6 (min)	DTC7 (min)	DTC8 (min)	OTC1 (min)	OTC2 (min)	OTC3 (min)
01	344	1291	1204	1189	1162	951	1208	917	686	623	793
02	361	1051	1204	1189	1262	–	–	783	686	834	793
03	115	1151	–	–	1142	699	1208	783	686	856	875
04	585	1291	1204	1189	1262	262	972	783	686	749	875
05	585	1163	763	1189	1042	951	1075	783	686	856	766
06	699	1291	1204	1189	927	951	1208	783	686	844	875
07	596	1169	1204	1080	1262	541	780	783	686	702	–
08	820	1169	242	1189	1262	951	1208	783	686	834	875
09	820	933	1204	1189	689	951	1030	–	686	856	875
10	465	671	894	1080	1262	–	–	475	686	586	556
11	–	–	1204	977	–	541	1006	783	–	706	875

DTC, domestic training camps; OTC, overseas training camps.

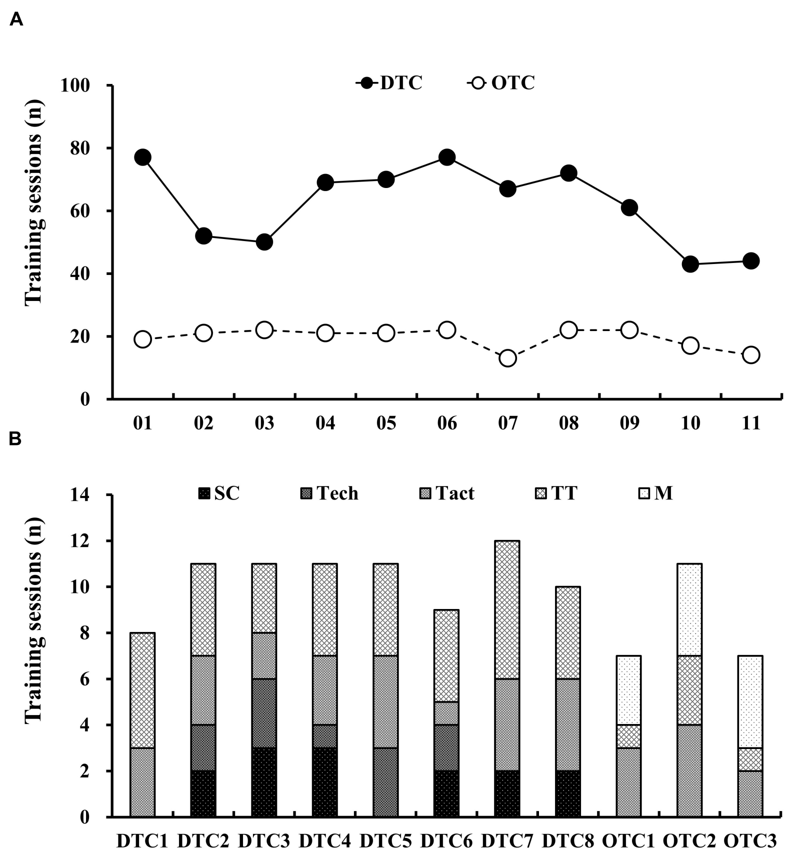

FIGURE 1 | The total number of training sessions during domestic and overseas training camps. **(A)** The total number of training sessions for each individual player. **(B)** The total number of training sessions for the group. DTC, domestic training camps; OTC, overseas training camps; S&C, strength and conditioning sessions; Tech, technical training sessions; Tact, tactical training sessions; TT, technical and tactical training sessions; M, friendly match.

Edward's method equation was used (Edwards, 1993) following the formula:

$$\text{TRIMP} = \textit{Time in HR zone } 1 * 1 + \textit{Time in HR zone } 2 * 2 + \textit{Time in HR zone } 3 * 3 + \textit{Time in HR zone } 4 * 4 + \textit{Time in HR zone } 5 * 5 \quad (1)$$

The HR zones were defined as 50–59% of maximal HR (HR_{max}), 60–69% of HR_{max}, 70–79% of HR_{max}, 80–89% of HR_{max}, and 90–100% of HR_{max} as HR zone 1, HR zone 2, HR zone 3, HR zone 4, and HR zone 5, respectively. The HR responses below 50% of HR_{max} were excluded in data collection. The HR_{max} was determined using individual peak HR responses during the Yo-Yo intermittent recovery level 1 test in the first DTC.

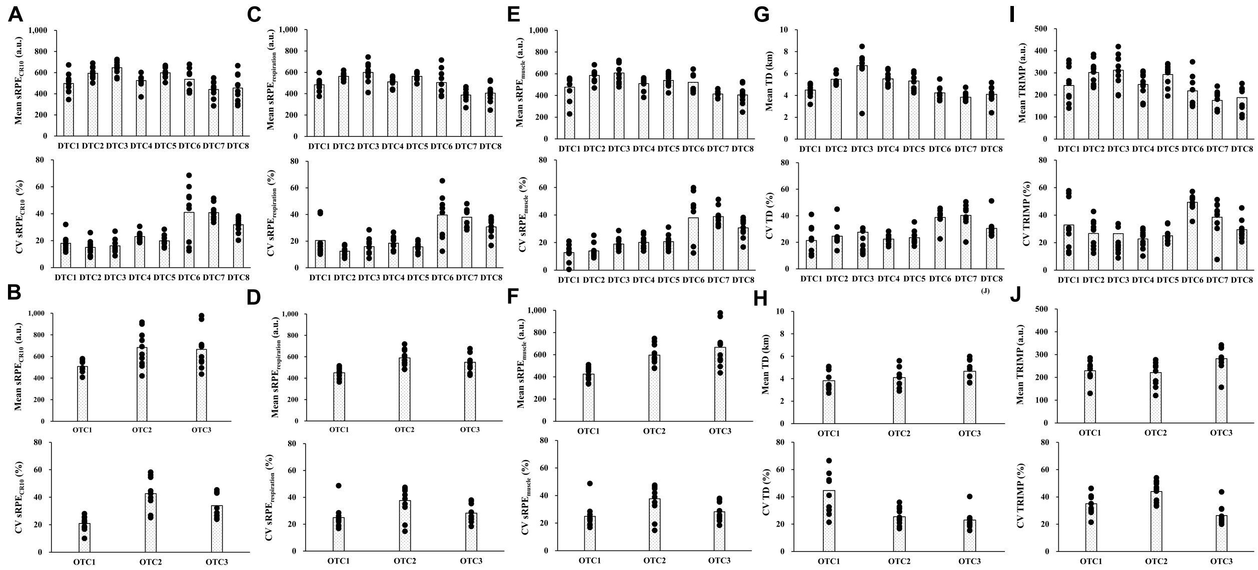

FIGURE 2 | The individual and group values of measured variables across the study period. Scatterplots present individual values during each training camp whereas bar charts present group average during each training camp. **(A)** Mean and CV $sRPE_{CR10}$ during the DTC; **(B)** mean and CV $sRPE_{CR10}$ during the OTC; **(C)** mean and CV $sRPE_{respiration}$ during the DTC; **(D)** mean and CV $sRPE_{respiration}$ during the OTC; **(E)** mean and CV $sRPE_{muscle}$ during the DTC; **(F)** mean and CV $sRPE_{muscle}$ during the OTC; **(G)** mean and CV total distance covered during the DTC; **(H)** mean and CV total distance covered during the OTC; **(I)** mean and CV training impulse during the DTC; and **(J)** mean and CV training impulse during the OTC. $sRPE_{CR10}$, session rating of perceived exertion CR10; $sRPE_{respiration}$, session respiratory perceived exertion; $sRPE_{muscle}$, session muscular perceived exertion; TD, total distance covered; TRIMP, training impulse; DTC, domestic training camps; OTC, overseas training camps. CV, coefficient of variation.

Total Distance

The TD is a sum of the traveled distance during training sessions and friendly matches. The same Polar Team Pro system (Polar Electro, Kemple, Finland) that is used for HR monitoring was used to record each player's traveled distance. Each player was mounted with a microsensor containing a 3-dimensional accelerometer, a gyroscope, and a digital compass that sampled at a rate of 200 Hz.

Statistical Analyses

The descriptive data were presented as means ± standard deviations (SD). Furthermore, the coefficient of variation (CV) was calculated for group or individual variability across the training camps. The average values of means and CV during a single training camp were used for statistical analyses. The normality of study variables was examined with the Kolmogorov–Smirnov test. Paired t-tests were used to compare the group average value of measured variables between DTC and OTC (data points: DTC = 682 data vs. OTC = 214 data). Standard differences of variables were examined by using Cohen's d effect size (ES). The standardized differences of the ES were interpreted as trivial (0.0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), or very large (>2.0) (Hopkins et al., 2009). Linear regression analysis was used to examine the relationship among (1) $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$; and (2) between perceived exertions ($sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$) and TRIMP/TD training loads. Significant differences between the means were set as $p < 0.05$. All statistical analyses were performed by SPSS version 25.0 software for Windows (IBM Corp, Armonk, NY, United States).

RESULTS

Comparisons Between Domestic and Overseas Training Camps

Individual and group values of TD, TRIMP, $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$ during DTC and OTC training camps are presented in **Figure 2**.

For the pairwise comparisons between DTC and OTC, the result showed that TD [$t = 13.592$, $p < 0.001$, ES = 2.79 (very large)] and TRIMP [$t = 7.357$, $p < 0.001$, ES = 1.12 (moderate)] during DTC were significantly higher than that of OTC. All RPE scales demonstrated higher absolute values. However, only RPE_{CR10} [$t = -2.260$, $p = 0.047$, ES = −0.80 (moderate)] and $sRPE_{CR10}$ [$t = 2.352$, $p = 0.041$, ES = −0.88 (moderate)] had significant differences (**Table 3**).

Linear Regressions of Rating of Perceived Exertions, Total Covering Distance, and Training Impulse

Figure 3 presents the linear regression among the $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$. The $sRPE_{CR10}$ demonstrated a good positive association to $sRPE_{respiration}$ during DTC ($r = 0.857$, $p = 0.001$) and OTC ($r = 0.863$, $p = 0.001$). The $sRPE_{CR10}$ demonstrated excellent positive association to

TABLE 3 | The perceived exertion of CR10, respiratory and muscular scales, training impulse, and total covering distance during the domestic and overseas training camps.

	Domestic camps		Overseas camps				Effect size (90% CI)	QI for effect magnitude (mean difference; ±90% CI)
	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Difference	*p*-Value		
RPE_{CR10} (a.u.)	4.92 ± 0.55	11.23	5.56 ± 0.94	16.97	−0.64	0.047	−0.80 (−1.55 – −0.09); moderate	Very likely (1.2/3.3/95.5)
$RPE_{respiration}$ (a.u.)	4.58 ± 0.36	7.90	4.79 ± 0.48	10.08	−0.21	0.183	−0.48 (−1.20 – 0.22); small	Likely (4.2/14.0/81.8)
RPE_{muscle} (a.u.)	4.67 ± 0.30	6.4	5.05 ± 0.78	15.53	−0.39	0.156	−0.62 (−1.36 – 0.09); moderate	Likely (5.3/5.9/88.8)
$sRPE_{CR10}$ (a.u.)	532.73 ± 60.81	11.42	615.01 ± 112.63	18.31	−82.27	0.041	−0.88 (−1.64 – −0.16); moderate	Very likely (1.1/2.5/96.3)
$sRPE_{respiration}$ (a.u.)	494.83 ± 44.33	8.96	528.37 ± 56.53	10.70	−33.54	0.115	−0.64 (−1.37 – 0.07); moderate	Likely (2.7/8.9/88.4)
$sRPE_{muscle}$ (a.u.)	504.37 ± 40.84	8.10	559.76 ± 91.05	16.27	−55.38	0.094	−0.76 (−1.51 – −0.05); moderate	Likely (3.0/4.3/92.7)
TRIMP (a.u.)	410.21 ± 82.71	20.16	319.64 ± 73.33	22.94	90.56	<0.001	1.12 (0.38 – 1.91); large	Most likely (99.8/0.2/0)
TD (km)	8.44 ± 0.79	9.35	5.61 ± 1.13	20.07	2.833	<0.001	2.79 (1.85 – 3.91); very large	Most likely (99.9/0/0)

RPE_{CR10}, rating of perceived exertion CR10; $RPE_{respiration}$, respiratory perceived exertion; RPE_{muscle}, muscular perceived exertion; $sRPE_{CR10}$, session RPE_{CR10}; $sRPE_{respiration}$, session $RPE_{respiration}$; $sRPE_{muscle}$, session RPE_{muscle}; SD, standard deviation; QI, qualitative inferences; CV, coefficient of variation; CI, confidence interval; TRIMP, training impulse; TD, total distance covered.

$sRPE_{muscle}$ during DTC ($r = 0.906$, $p < 0.001$) and OTC ($r = 0.900$, $p < 0.001$). Additionally, the $sRPE_{respiration}$ demonstrated good positive association to $sRPE_{muscle}$ during DTC ($r = 0.763$, $p = 0.006$) and OTC ($r = 0.924$, $p < 0.001$).

In **Figure 4**, the $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$ demonstrated poor positive association to TD during DTC ($sRPE_{CR10}$: $r = 0.090$, $p = 0.792$; $sRPE_{respiration}$: $r = 0.008$, $p = 0.980$; $sRPE_{muscle}$: $r = 0.238$, $p = 0.480$) and OTC ($sRPE_{CR10}$: $r = 0.065$, $p = 0.849$; $sRPE_{respiration}$: $r = 0.092$, $p = 0.789$; $sRPE_{muscle}$: $r = 0.008$, $p = 0.982$).

In **Figure 5**, the $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$ demonstrated poor positive association to TRIMP during DTC ($sRPE_{CR10}$: $r = 0.135$, $p = 0.692$; $sRPE_{respiration}$: $r = 0.144$, $p = 0.672$; RPE_{muscle}: $r = 0.031$, $p = 0.928$). But OTC ($sRPE_{CR10}$: $r = 0.586$, $p = 0.058$; $sRPE_{respiration}$: $r = 0.469$, $p = 0.145$; $sRPE_{muscle}$: $r = 0.574$, $p = 0.065$) had higher positive association than DTC.

DISCUSSION

This study is the first to quantify training loads using $RPE_{respiration}$ and RPE_{muscle} during DTC and OTC in male futsal players. The primary findings revealed that DTC demonstrated larger TD and TRIMP than that of OTC. Whereas RPE_{CR10} was significantly larger during OTC than that of DTC, no significant differences in $RPE_{respiration}$ and RPE_{muscle} were observed between DTC and OTC. The second finding in this study was that $RPE_{respiration}$ and RPE_{muscle} demonstrated a positive linear association to RPE_{CR10}. Thus, either $RPE_{respiration}$ or RPE_{muscle} can be used to quantify internal load during DTC and OTC in futsal players. Additionally, individual variability of measuring variables varied from camp to camp. Three different RPE scales showed similar dispersion and tendency of individual and group values across the DTC. Finally, TD and TRIMP are independent markers to training loads quantified by RPE scales during short-term futsal training camps.

We found that mean values of TD and TRIMP were significantly larger during DTC than that of OTC. It seems that there is a large demand of physical engagement during futsal DTC. Conversely, the $RPE_{respiration}$ and RPE_{muscle} demonstrated no difference between the two different types of training camps. These findings highlighted the discrepancy of subjective and objective assessments of training loads in futsal DTC and OTC. Conversely, the different activity profiles that experienced between DTC (generally focused on fitness development, player selection, and technical evaluation) and OTC (usually incorporates more friendly matches and fewer training sessions to prepare for competition) could be a factor to explain these findings (Chen et al., 2020). Another possible explanation for these findings could be greater intersubject variability of RPE measures. Nevertheless, it is challenging to compare our observations with other populations, levels of players, or sports due to limited studies reporting internal or external loads during OTC.

It is interesting to note that the RPE_{CR10} was significantly larger during OTC than that of DTC. Although larger values of $RPE_{respiration}$ and RPE_{muscle} were observed during OTC, the results did not approach statistical significance. Indeed, the RPE_{CR10} is a self-report tool to reflect the overall engagement of psychophyiolgoical efforts during the training or match. The higher values of RPE_{CR10} and $sRPE_{CR10}$ reported during OTC might be related to a high frequency of friendly matches. Futsal is a high-intensity intermittent sports (Spyrou et al., 2020) with characteristics of quick decision-making on top of highly demanding technical and tactical performance (Corrêa et al., 2016). It seems that the players experienced higher perceptive loads rather than physiological strains during OTC as evidenced by TRIMP and TD metrics. However, the psychological stress and mental effort were not evaluated in this study. Thus, the overall contribution of psychological aspects on the intensity of RPE level is unknown.

We observed a positive association between $RPE_{respiration}$ and RPE_{muscle} scales during both DTC and OTC. These

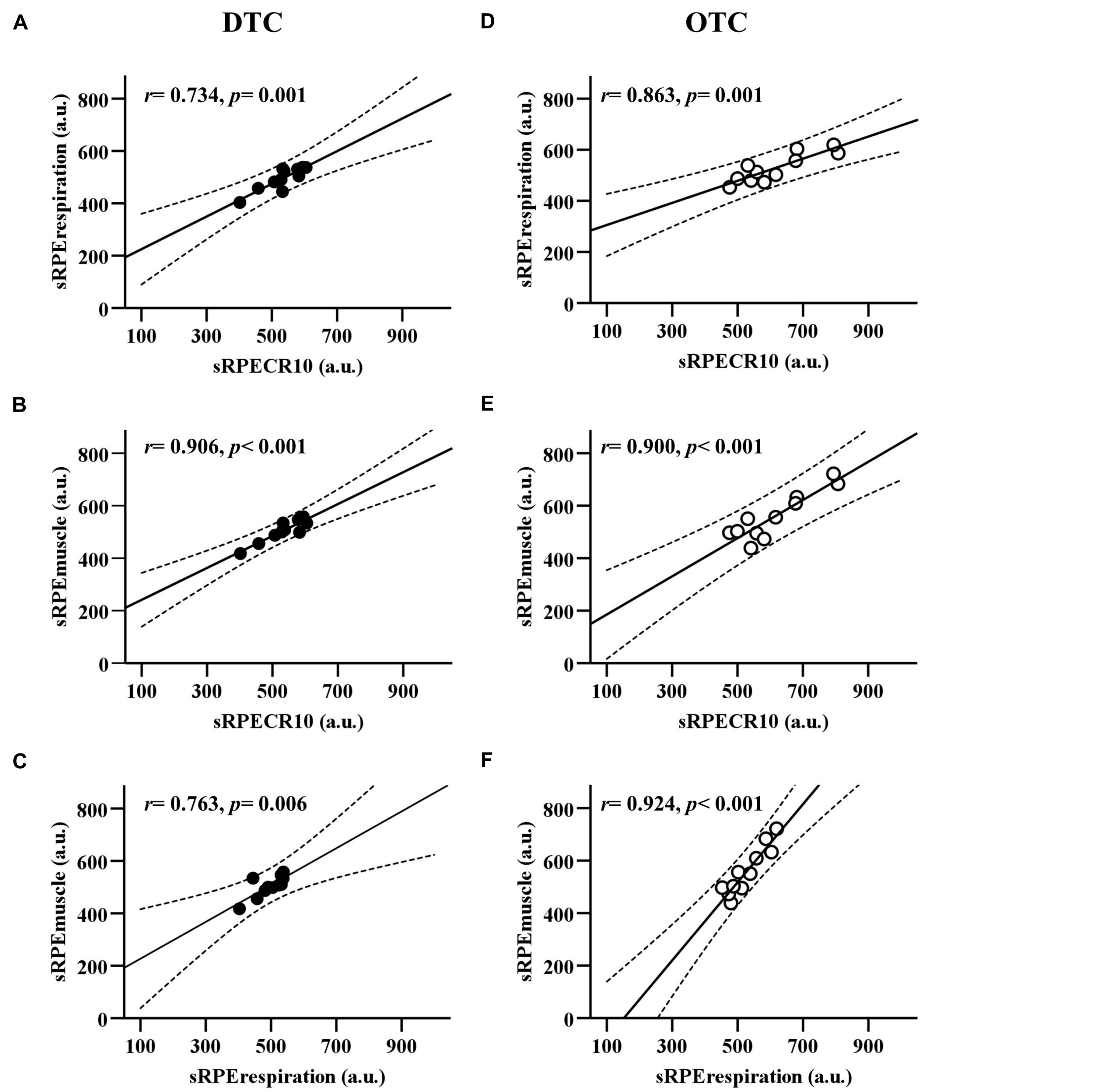

FIGURE 3 | The linear regression between $sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$ during domestic and overseas training camps. **(A)** Comparison between $sRPE_{CR10}$ and $sRPE_{respiration}$ during DTC. **(B)** Comparison between $sRPE_{CR10}$ and $sRPE_{muscle}$ during DTC. **(C)** Comparison between $sRPE_{respiration}$ and $sRPE_{muscle}$ during DTC. **(D)** Comparison between $sRPE_{CR10}$ and $sRPE_{respiration}$ during OTC. **(E)** Comparison between $sRPE_{CR10}$ and $sRPE_{muscle}$ during OTC. **(F)** Comparison between $sRPE_{respiration}$ and $sRPE_{muscle}$ during OTC. $sRPE_{CR10}$, session rating of perceived exertion CR10; $sRPE_{respiration}$, session respiratory perceived exertion; $sRPE_{muscle}$, session muscular perceived exertion; DTC, domestic training camps; OTC, overseas training camps.

findings are supported with previous studies that observed longitudinal changes in $RPE_{respiration}$ and RPE_{muscle} scales in young professional adult soccer players during weekly training sessions and in-season matches (Los Arcos et al., 2014, 2016, 2017). The RPE_{muscle} and $RPE_{respiration}$ scales showed similar features when quantifying the training load during weekly training sessions of a competitive period in professional soccer players (Los Arcos et al., 2017). Furthermore, different RPE scales permit researchers to obtain similar patterns of internal load during short-term specific training sessions. McLaren et al. (2020) recently demonstrated the usefulness of $RPE_{respiration}$ and RPE_{muscle} scales in detecting improvements in high-intensity running profiles during a 2-week repeated sprint training intervention in semiprofessional soccer players. In this study, the positive association identified in all RPE scales indicates the potential usefulness of pictorial RPE measures in quantifying internal load in futsal training.

The results of linear regressions show no relationships between RPE scales and TD/TRIMP. This finding indicated independent markers of training load monitoring between the subjective and objective tools. Subjective assessment of training load can be used to understand the variation in an individual's perception of daily changes in psychological and physiological status during sports training. Conversely, objective assessment of training load provides a quantitative measure of physiological responses and exercise performance

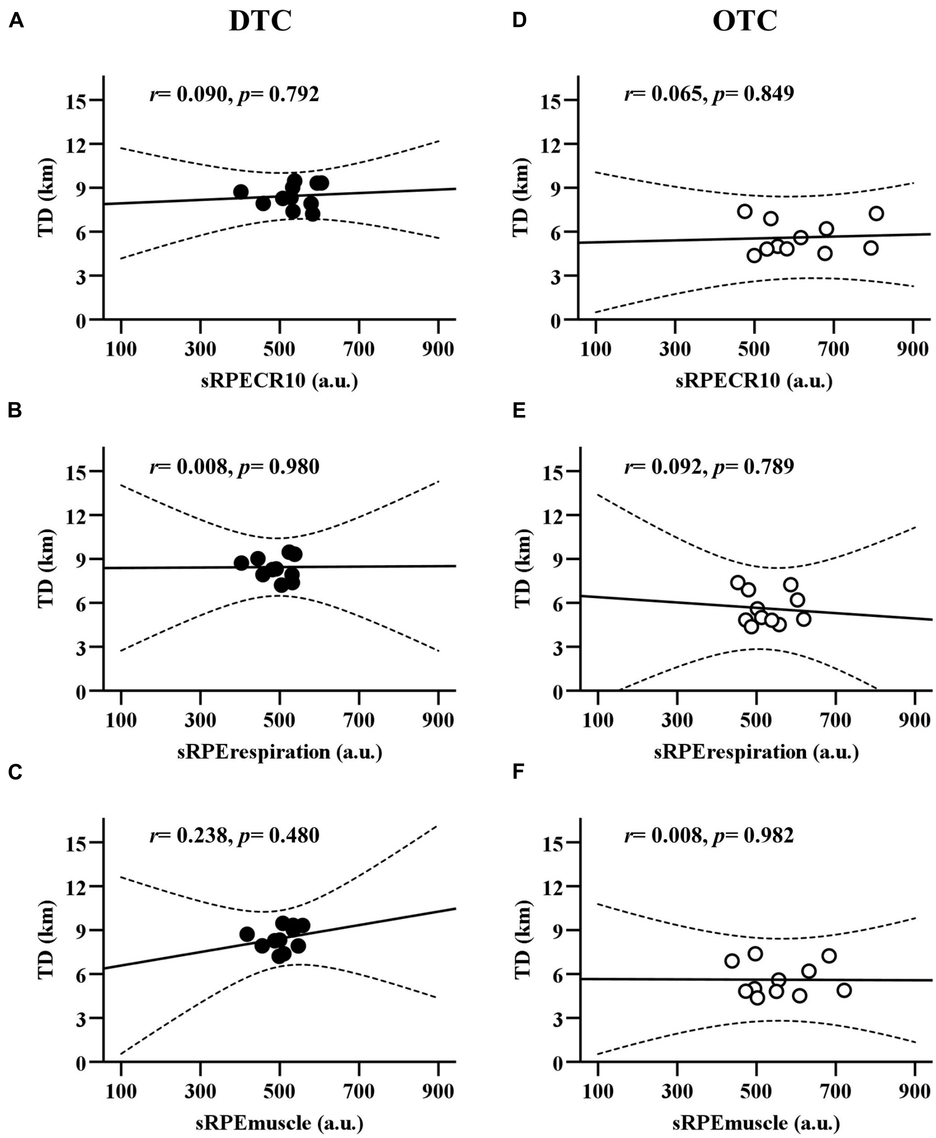

FIGURE 4 | The linear regression between the RPE (RPE_{CR10}, $RPE_{respiration}$, and RPE_{muscle}) and the total distance covered during domestic and overseas training camps. **(A)** Comparison between TD and $sRPE_{CR10}$ during DTC. **(B)** Comparison between TD and $sRPE_{respiration}$ during DTC. **(C)** Comparison between TD and $sRPE_{muscle}$ during DTC. **(D)** Comparison between TD and $sRPE_{CR10}$ during OTC. **(E)** Comparison between TD and $sRPE_{respiration}$ during OTC. **(F)** Comparison between TD and $sRPE_{muscle}$ during OTC. TD, total distance covered; $sRPE_{CR10}$, session rating of perceived exertion CR10; $RPE_{respiration}$, session respiratory perceived exertion; RPE_{muscle}, session muscular perceived exertion; DTC, domestic training camps; OTC, overseas training camps.

to understand the accumulation of training and match loads. Collectively, our findings suggested no relationship between RPE scales and TRIMP/TD variables during futsal DTC and OTC. A combination of subjective and objective assessments to evaluate training loads in futsal training is recommended.

It should be noted that a within-subject approach was used during this study period (Costa et al., 2019, 2021; Figueiredo et al., 2021). Compared to TD and TRIMP, our results demonstrated that three different RPE scales showed similar dispersion and tendencies between individual and group values across the DTC. However, such observations may not exist during the OTC (see **Figure 2**). It is possibly related to the difference in training tasks among the OTC. In our study samples, the OTC consisted of several friendly matches to test the team's competitive level. Costa et al. (2021) found that a training camp consisting of training sessions and friendly matches demonstrated a large variability of $sRPE_{CR10}$ in female football players. Interestingly, there was a long interval between DTC 5 and DTC 6 (83 days) in our study. Despite the similar training contents with DTC 2, 3, and 4, a large dispersion of individual training load was observed in DTC 6. This finding was related to the initial fitness level before the training camp and competition status in the participants' home teams (2-week break during the Chinese New Year, and no competition schedule). During the periodic training camps,

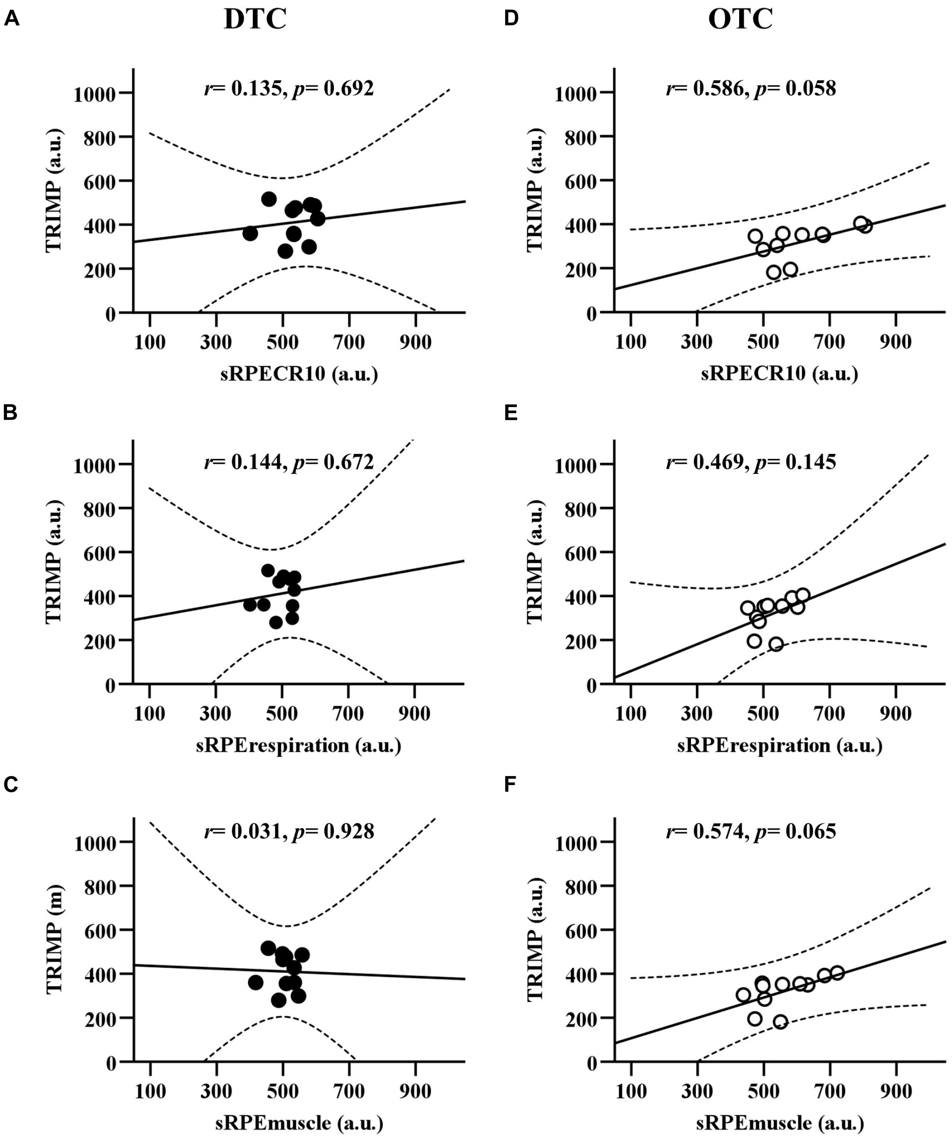

FIGURE 5 | The linear relationship between session RPE ($sRPE_{CR10}$, $sRPE_{respiration}$, and $sRPE_{muscle}$) and training impulse during domestic and overseas training camps. **(A)** Comparison between TRIMP and $sRPE_{CR10}$ during DTC. **(B)** Comparison between TRIMP and $sRPE_{respiration}$ during DTC. **(C)** Comparison between TRIMP and $sRPE_{muscle}$ during DTC. **(D)** Comparison between TRIMP and RPE_{CR10} during OTC. **(E)** Comparison between TRIMP and $sRPE_{respiration}$ during OTC. **(F)** Comparison between TRIMP and $sRPE_{muscle}$ during OTC. TRIMP, training impulse; $sRPE_{CR10}$, session rating of perceived exertion CR10; $sRPE_{respiration}$, session respiratory perceived exertion; $sRPE_{muscle}$, session muscular perceived exertion; DTC, domestic training camps; OTC, overseas training camps.

coaches and strength and conditioning practitioners should consider the large individual difference in fitness level when the players return for training camps.

The first limitation of this study is that respiratory and muscular RPE used pictorial rating to quantify the perception of sensory feedback, compared to arbitrary units used in RPE_{CR10}. This study players had extensive experience using the pictorial $RPE_{respiration}$, RPE_{muscle}, and $sRPE_{CR10}$ measurements. Despite similar reports among different RPE scales found in our study, there still exists the potential that other populations, such as players with less training experience or those who are not familiar with this method, may show differing results. Second, the different perceived efforts might be related to the players' initial fitness capacity. This study did not report the association between fitness capacity and individual perception of training stresses (Azcárate et al., 2020). A potential bias of the individual peak HR that changed across the timeline of training camps could be the third limitation of this study. The peak HR determined during the Yo-Yo intermittent recovery level 1 test in the first OTC may not be equivalent to actual HR_{max} in each training camp engagement. Finally, the task difference during DTC and OTC may result in large intraindividual variability in this study. The main focus of friendly matches during OTC could lead to a fluctuation of daily training loads and recovery status to more/less playing time per individual. Future studies need to measure these individual changes during the training camps.

The present findings revealed significant positive correlations among RPE_{CR10} and pictorial $RPE_{respiration}$ and RPE_{muscle} during the futsal DTC and OTC. Our study reported that pictorial RPE measures and RPE_{CR10} have similar outcomes as monitoring tools during futsal training. Coaches and sports practitioners are encouraged to use one of the RPE measures concurrently with time spent in HR zones and TD measures during futsal training camps.

CONCLUSION

In conclusion, TD and TRIMP of short-term DTC were larger than that of short-term OTC. However, the RPE_{CR10} is higher during OTC than that of DTC. No differences in perceived measures of muscular and respiratory RPE were identified. Additionally, three different RPE measures showed similar individual dispersion and group tendency across the DTC. The interpretation of perceived efforts *via* respiratory, muscular, and Borg CR10 quantifications provides a valuable resource in monitoring internal load in futsal DTC and OTC. No relationships among the perceived measures, TRIMP, and TD were observed in this study highlighting that it is essential to implement multiple tools when recording training loads in futsal players. Using a combination of subjective and objective measures to monitor training loads during short-term futsal training camps is warranted.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Ethics Committee of the University of Taipei. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

Y-XL contributed to the study conceptualization, project administration, investigation, methodology, and writing (including reviewing and editing) of the manuscript. FMC and PB contributed to the study conceptualization and writing (including reviewing and editing) of the manuscript. ZC-M and C-HC contributed to the study data analysis and writing (including reviewing and editing) of the manuscript. S-CC contributed to the statistical analysis and writing (including reviewing and editing) of the manuscript. C-DK and Y-SC contributed to the study conceptualization, methodology, supervision, and writing (including reviewing and editing) of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This study was supported by the grant V96C1-153 of Taipei Veterans General Hospital, Taiwan.

ACKNOWLEDGMENTS

The authors would like to thank the head coach Adil Amarante, team staff, and players who volunteered for this study.

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Conflict of Interest: C-DK is a consultant for Leadtek Research Inc.

The remaining 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.

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