RICYDE. Revista Internacional de Ciencias del Deporte
doi: 10.5232/ricyde
Rev. Int. cienc. deporte

RICYDE. Revista Internacional de Ciencias del Deporte
Volume XVII - Year XVII
Pages: 88-101 - ISSN: 1885-3137
Issue 63 - January 2021

https://doi.org/10.5232/ricyde2021.06307

A Principal Component Analysis in futsal according to game halves: A case study of an amateur futsal cup final

Análisis de componentes principales en fútbol sala según las partes de juego: un estudio de caso en una final de copa amateur

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Abstract

Principal Component Analysis (PCA) has not been used to assess the principal component (PC) of players´ external training loads (TL) in futsal. In addition, no previous study has analyzed the PC of players´ external TL depending on the half of the match in futsal. Thus, this study aimed to assess the PC of players´ external TL considering an entire official futsal match distinguishing by halves (1st and 2nd halves). Two teams of twelve amateur futsal players (Spanish 3rd division) participated in the final match of the futsal cup and external TL was quantified using eight antennas ultra-wideband technology. Through PCA statistical analysis, 10 variables formed the 10 PC. Specifically, three PC for the entire match, four for the 1st half, and three for the 2nd half were extracted. Considering the match as a whole, three PC explained the players´ external TL formed by eight variables: distance covered (m/min), distance covered at high speed running (m/min), distance covered at explosive speed (m/min), total accelerations (n/min), total decelerations between 2-1 m/s/s (n/min), distance covered at 24-50 km/h (m/min), total impacts between 8-100g (n/min) and Jumps performed (n/min). The PC variables differed between halves: a) in the 1st half 74.5% was explained by four PC composed of 8 variables in total, and b) in the 2nd half 67.6% was explained by three PC. The results suggest that the use of only one PC could potentially lead to an underestimation of the external TL demands in futsal matches. It seems that a combination of 3-4 PC from a total of 8 to 10 variables are required to explain senior amateur futsal official games. In addition, the match half should be considered to assess the external TL in team sports.

Key words: PCA; game-analysis; training load; quantification.

Resumen

El análisis de componentes principales (ACP) no se ha utilizado para conocer los componentes principales (CP) de las cargas de entrenamiento (CE) de los jugadores en fútbol sala. Además, no se han publicado estudios que analicen los CP de la CE de los jugadores en función del período de juego en fútbol sala. Por lo tanto, este estudio tuvo como objetivo evaluar los CP de la CE de los jugadores considerando un partido de fútbol sala oficial diferenciando por períodos. Dos equipos de doce jugadores amateurs de fútbol sala (3a división española) participaron en una final de la copa de fútbol sala. A través del análisis estadístico de CP, 10 variables formaron los 10 CP. Concretamente, se extrajeron 3 CP para el partido en su totalidad, 4 para el primer período y 3 para el segundo período. Considerando el partido como un todo, 3 CP formados por 8 variables explicaron la CE de los jugadores: Distancia cubierta (m / min), carrera a alta velocidad (m / min), distancia recorrida a velocidad explosiva (m / min), número de aceleraciones totales (n / min), número de desaceleraciones de 2 a 1 m/s (n / min), distancia cubierta de 24 a 50 km/h (m / min), impactos 8-100g (n / min) y saltos (n / min). Las variables de los CP diferían entre períodos: a) en el primer período, 4 CP explicaron el 74.5% de la CE de los jugadores, mientras que b) en el segundo período, 3 CP explicaron el 67.6%. Los resultados sugirieron que el uso de un solo CP podría conducir a una subestimación de las demandas de CE en los partidos de fútbol sala. Parece que se requiere una combinación de 3-4 CP formados por un total de 8 variables para explicar los partidos oficiales de fútbol sala amateur. Además, se debe considerar el ACP por períodos para evaluar el CE en los deportes de equipo.

Palabras clave: PCA; análisis del juego; carga de entrenamiento; cuantificación.

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Received: July 23, 2020; Accepted: November 11, 2020

Introduction

The training load (TL) is habitually quantified in team sports because it is related, at least partially, to changes in players´ physical fitness performance (Jaspers, Brink, Probst, Frencken & Helsen, 2017) and injury occurrence (Bowen, Gross, Gimpel, & Li, 2017; Owen, Forsyth, Wong, Dellal, Conelly, & Chamari, 2015). In addition, its quantification is of interest for sports teams because the optimal weekly TL distribution is pivotal to ensure sufficient after-game recovery and prevent pre-match fatigue (Akenhead, Harley, & Tweddle, 2016; Coutinho, Gonçalves, Figueira, Abade, Marcelino, & Sampaio, 2015; Fessi, Zarrouk, Di Salvo, Filetti, Barker, & Moalla, 2016; Jeong, Reilly, Morton, Bae, & Drust, 2011; Malone, Di Michele, Morgans, Burgess, Morton, & Drust, 2015; Rico-González, Méndez-Villanueva, & Los Arcos, 2020). The quantification of TL is based on both external (e.g. distance) and internal (e.g. heart rate) indicators of effort intensity (Buchheit, 2014). Effort intensity is then computed with training time to derive compound TL measures. Specifically, in futsal, TL has been assessed to analyze its distribution in a professional futsal team and verify its subsequent effects on physical performance, muscle damage, and hormonal status (Miloski, Freitas, Nakamura, Nogueira, & Bara-Filho, 2016). It was found that the training program demonstrated higher TL during the halves with a low incidence of matches, emphasis on endurance and strength training during the pre-season, and speed and power training throughout the in-season (Miloski et al., 2016). Nakamura, Antunes, Nunes, Costa, Esco, & Travassos (2018) found that the players who accumulated higher perceived TL displayed smaller improvements in the Yo-Yo Intermittent Recovery Test, level 1 (Yo-Yo IR1) performance. Wilke, Wanner, Santos, Penna, Ramos, Nakamura, and Duffield (2020) assessed elite male futsal players to determine whether daily perceived recovery was explained from a multifactorial single-session classification of recovery (i.e. faster vs. slower) or other circumstantial factors (i.e. previous training load, self-reported sleep, or phase of the microcycle). The results showed that neither recovery classification nor prior TL influenced perceived recovery during the pre-season. However, a higher total quality of recovery scale was evident with better self-reported sleep quality, whereas lower values were associated with phases of the training week. Additionally, Clemente, Martinho, Calvete, & Mendes (2019) analyzed the variations of internal load (IL) and well-being between normal and congested weeks in professional futsal players and variations in training days (MD-1, MD-2 and MD-3 [matchday -1, -2, and -3, respectively]) within weeks. The major findings of this study revealed meaningful increases of IL, muscle soreness, and fatigue in normal weeks in comparison to congested ones. Within-week changes were also observed, with the greatest loads being observed on MD-3, during standard weeks and on MD-2 during congested weeks, suggesting the relevance of the matchday on the organization of the training week.

The official match is the most important session of the week, and futsal players should be prepared to respond to its physical-physiological demands. Thus, the assessment of the match TL is necessary to design the training week and physical fitness training. Considering external indicators of effort intensity, the total distance covered ranged from 3.251 to 7.877 m and the distance covered per minute from 117.3 ± 11.6 to 121 ± 16 (Matzenbacher, Pasquarelli, Rabelo, & Stanganelli, 2014) according to the competition level of the professional futsal players. Around 28.5% of the total distance covered was at medium-intensity running (10.9 – 18 km.h-1), 13.7% at high-speed running (18.1–25 km.h-1) and 8.9% at sprint (> 25.1 km.h-1) in professional futsal players (Barbero-Alvarez, Soto, Barbero-Álvarez, & Granda-Vera, 2008). In addition to the competition level, it seems that other situational variables (Méndez-Domínguez, Gómez-Ruano, Rúiz-Pérez, & Travassos, 2019; Rico-González, Pino-Ortega, Clemente, & Los Arcos, 2020) as for example the half of the game, also determine external match TL (Milioni et al., 2016; Bueno, Caetano, Costa Pereira, De Souza, Moreira, Nakamura, Cunha, & Moura, 2014). Previous studies found that each player covers 3,133.2 m for the entire game and 2,133.9 m and 1,028.5 m for the in-play and out-of-play phases (Bueno et al., 2014). On the other hand, Bueno et al. (2014) did not find significant differences between distance covered by a player in the 1st half (1,710.6 m) and in the 2nd half (1,635.9 m), but Milioni et al. (2016) found significant differences between the meters covered by the players as the minutes went on (1st half: 103.2 ± 4.4 m.min−1; 2nd half: 96.4 ± 7.5 m.min−1, p = 0.00). The considerable differences between studies suggest the need for the quantification of the external TL in other teams; especially in amateur futsal players. Although many players compete at the regional level around the world, little is known about this population.

The increasing interest in analyzing training and matches and the use of micro-technology and other micro-electromechanical systems (MEMS) has allowed access to more objective external TL data (Agras, Ferragut, & Abraldes, 2016). In light of the great amount of variable data, it is a challenge to identify those variables which provide the most relevant information about TL (Agras et al., 2016). For example, Principal Component Analysis (PCA) has been used to explain the variance of a large set of dependent variables by transforming them into the important independent original variables (Groth, Hartmann, Klie, & Selbig, 2013; Weaving, Marshall, Earle, Nevill, & Abt, 2014). It is necessary to highlight that coaches usually require simple and explicit reports of the load behavior of their teams and do not have time to explore one by one all the variables that new technologies provide, that is why PCA has proven to be an effective tool for the selection of a few variables that explain general behavior, in this case external load.

PCA has been used in several team sports such as soccer, basketball and rugby to assess external TL (Casamichana, Castellano, Gómez Díaz, Martín-García, 2019; Oliva-Lozano, Rojas-Valverde, Gómez-Carmona, Fortes, & Pino-Ortega, 2020; Pino-Ortega, Gómez-Carmona, Nakamura, & Rojas-Valverde, 2020; Svilar, Castellano, & Jukic, 2018; Weaving et al., 2014). In soccer, two recent studies have analyzed external load demands during competitive and training sessions (Casamichana et al., 2019; Oliva-Lozano et al., 2020). The first extracted the most representative variables of a whole season of professional soccer team matches (Oliva-Lozano et al., 2020) and the second compared the internal and external load of both training and match sessions (Casamichana et al., 2019). Based on these results the variables that explained most of the locomotion behavior of professional soccer players were the combination of high intensity actions such as: acceleration, deceleration, distance covered over 19.8km/h, high metabolic load distance, dynamic stress load, maximum speed and distance covered at sprint speed (over 25.2km/h) (Casamichana et al., 2019; Oliva-Lozano et al., 2020).

Although there are studies in futsal that have reported variables that explained certain behavior in this sport, there are no studies reporting the use of PCA as an objective method to select external or internal load variables. In this kind of studies, the variables are usually selected using technical criteria or are limited by the technology used. Specifically, the variables that have been selected in previous research were: distance covered, total duration of activities, total frequency of activities, effort distance, and effort duration (Bueno et al., 2014; Dogramaci, Watsford, & Murphy, 2011). Thus, the aim of this study was to explore the main external load variables during an official futsal match by halves based on PCA analysis.

Methods

Participants

Two teams of twelve Spanish amateur futsal players (3rd division) participated in the final match of the futsal Cup on May 31, 2019. The match was played on indoor stadium, and it started at 11:30 a.m. and the temperature was 20ºC. The duration of the playing time is divided into 2 halves of 20 min with clock stops in every dead ball. No extra time was played. The organization and each player gave their written informed consent to participate in the research. The study, conducted according to the Declaration of Helsinki (2013), was approved by the Bioethics Commission of the University.

Assessment method

Considering that there are several principles of use as well as general and specific criteria that could affect the quality of the data obtained during sport locomotion and tracking assessments, the present study methodology followed the protocol by Rico-González, Los Arcos, Rojas-Valverde, Clemente, and Pino-Ortega (2020) in order to guarantee a strict description of the use of the technology. As external variables were recorded from both ultra-wideband (UWB) and microelectromechanical (MEMS) devices and considering that both technologies are based on different principles of use, the method is based on two criteria surveys. For the use of UWB 21 points out of 23 were explained (i.e. GC1, GC2, GC3, GC4, GC5, GC6, GC7, GC8, GC9, GC10, LPS1, LPS2, LPS3, LPS4, LPS5, LPS6, LPS7, LPS8) while for the use of MEMS 16 points out of 20 were explained (i.e. GC1, GC2, GC3, GC4, GC5, GC6, GC7, GC8, GC9, GC10, MEMS1, MEMS2, MEMS4, MEMS5). These results correspond to 91% and 80%, respectively. The rest of the items cannot be explained as the authors did have not this information.

Technology

Positional data were gathered by a time-motion tracking system which includes a Local Positioning System (LPS) device, based on UWB technology, and an Inertial Measurement Unit (IMU; WIMU PROTM, RealTrack Systems, Almeria, Spain). The UWB technology operates on a much wider frequency band than other traditional radio communication technologies (at least, 0.5 GHz), and a previous study did not report any problems in UWB-based tracking system accuracy in multipath conditions (i.e. 28 devices turned on) (Bastida Castillo, Gómez-Carmona, De la Cruz Sánchez, & Pino-Ortega, 2018). This system holds both FIFA International Match Standard and Quality certificates. Each device consists of an internal microprocessor, 2 GB flash memory, and a high-speed USB interface, to record, store, and upload data.

Data collection

<u>*Ultra-wideband*</u>

Data collection was made based on Rico-González et al. (2020). The data were recorded in a training space far from metallic materials. The UWB system was composed of a reference system and tracked devices carried by the players. The former comprised antennae that are transmitters and receivers of the radio-frequency signals. The antennae (mainly the master antenna) computerize the position of the devices that are in the play area, while the device receives that calculation using Time Difference of Arrival (TDOA). The eight antennae were installed five hours before the match following a previous study (Pino-Ortega, Bastida-Castillo, et al., 2020), forming an octagon (Figure 1) for better signal emission (4.5 m from the perimeter line for antennae located in the corners, and 5.5 m from the perimeter line for the antennae located in the middle of the court and behind the goals) and reception at a height of 3 m and held by a tripod (Pino-Ortega, Bastida Castillo, et al., 2020). Once installed, they were switched on one by one, with the master antenna turned on last. From that moment, it was necessary to wait for 5 minutes to avoid technology lock in which the antennae calculate their positioning and the distance between them (Rico-González, Los Arcos, et al., 2020). To allow data time synchronization, the master antennae managed the time using a standard clock which allows data recording at the same time. When all devices were switched on in the centre of the reference system a process of automatic recognition between antennae and devices was carried out during 1 minute. In this study, the raw data were recorded at an 18 Hz sampling frequency because low frequencies have shown to have a lower quality of measurement, and 18 Hz with UWB has not shown less accuracy because of noise problems. The conditions were maintained with low temperatures, humidity gradients, and slow air circulation in order to allow easier positioning. This UWB system has demonstrated valid and reliable measures during continuous situations (Bastida-Castillo, Gómez-Carmona, De La Cruz Sánchez, et al., 2019).

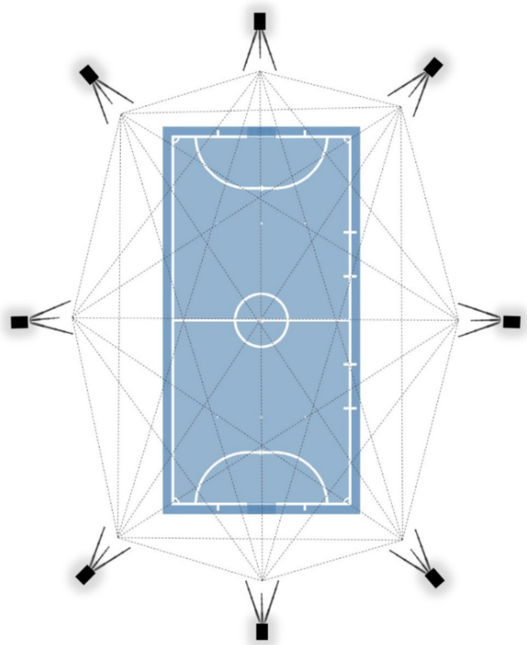

Figure 1. The UWB reference system disposition during the study

Inertial Measurement Units

Pino-Ortega, Bastida-Castillo et al. (2020) assessed the validity of the inertial measurement unit (IMU; WIMU PROTM, Real Track Systems, Almeria, Spain). The devices were attached to the players’ upper backs in a pocket attached to a tight-fitting garment, placed between the scapulae at the T2-T4 level to avoid unwanted movement. The tight-fitting garments were the same for each player in each game. The calculation of the velocity was made through positional differentiation (Malone et al., 2017). From the results extracted, an algorithm is applied to extract acceleration data (the manufacturer did not specify the algorithm).

Data processing

Following Rico-González et al. (2020), data were downloaded after the session. S PROTM software (RealTrack Systems, Almeria, Spain) was used to analyze and export the data on the x- and y- position coordinates (Bastida-Castillo, Gómez-Carmona, De la Cruz-Sánchez, et al., 2019). Before the match started, the EPTS were placed in a harness which was anatomically adjusted. At the end of the match, the raw data from the devices were downloaded and exported to Excel using the SPROTM software, where the time marks made in each player's receptor during the tracked time were synchronized using the S VIVOTM software. The players were considered for analysis if they played more than 60% of the effective time of play per half, to homogenize the sample based on the time of participation (Sampaio, Drinkwater, & Leite, 2010). The goalkeepers were excluded from the study because their technical-tactical requirements differ from those of field players (White et al., 2018).

External load variables

Since all players did not play the same amount of time during the match, from a total of approximately 250 variables registered by the inertial devices, only 52 time-, maximum- and mean-related variables (i.e. external load per minute) were finally considered during PCA procedure (Oliva-Lozano et al., 2020). Therefore, the following 10 variables were extracted in both halves and whole match: total distance covered (Dist, m/min), distance covered at high speed running (HSR, m/min), distance covered at explosive speed (DistExpl, m/min), total accelerations (Acctotal, n/min), total decelerations between 2-1 m/s/s (Dec2-1m/s/s, n/min), total decelerations between 10-6 m/s/s (Dec10-6m/s/s, n/min), distance covered at 24-50km/h (Dist24-50km/h, m/min), distance covered at 0-6km/h (Dist0-6km/h, m/min), total impacts between 8-100g (Impacts8-100g, n/min) and Jumps performed (Jumps, n/min).

Statistical analysis

The results are shown as mean and standard deviation (M±SD). The normal distribution of the data was confirmed using the Kolmogorov-Smirnov protocol and the homogeneity of the variance with the Levene test. All relative variables were examined for each team. A correlation matrix was performed for each team's locomotion variables prior to Principal Component Analysis (PCA) in order to select uncorrelated representative variables (Federolf, Reid, Gilgien, Haugen, & Smith, 2014). An $r < 0.7$ correlation between variables was considered for extraction (Tabachnick & Fidell, 2007) and variables with variance = 0 were excluded. The 10 selected variables through the previous processes were scaled and centred (Z-scored). The Kaiser-Meyer-Olkin values and Barlett´s Sphericity test confirmed that PCA was suitable (KMO= 0.56-0.7) (Bartlett, 1954; Kaiser, 1960). Eigenvalues >1 were considered for the extraction of principal components (Kaiser, 1960). A VariMax-orthogonal rotation method was performed in order to identify a high correlation of components and guarantee that each principal component offered different information (Kaiser, 1960). A threshold of 0.6 in each PC loading was retained for interpretation, extracting the highest factor loading when a cross-loading was found between components (Kaiser, 1960). Statistical significance was set at $p<0.05$ and the analyses were performed with SPSS software (version 24, IBM, Chicago, U.S.A.).

Results

The descriptive data (mean ± SD) of the external TL for each half and the entire match is provided in Table 1.

Through PCA statistical analysis, 10 variables formed the 10 principal components (PC) (Table 2). Specifically, three PC were extracted for the whole match, while four were extracted for the 1st half and three for the 2nd half. Although 10 variables were extracted in total, each half or the entire match was explained by 8 variables (Table 2).

Three PC explained 63.5% of the total variance in whole match behavior. The first PC was composed of Dist (m/min), $Dist_{Expl}$ (m/min) and $Dist_{24-50km/h}$ (m/min) (variance = 31.45). The second PC was composed of Acc_{total} (n/min), $Dist_{0-6km/h}$ (m/min), $Impacts_{8-100g}$ (n/min) and Jumps (n/min) (variance = 17.05). The third PC was composed of $Dec_{10-6m/s/s}$ (n/min) (variance = 14.58) (Table 2).

Differences were found when the halves were compared between themselves and with the whole match. Four PC composed of 8 variables in total explained 74.5% of the variance in the 1st half. The first PC was composed of Dist (m/min), $Dist_{Expl}$ (m/min) and $Impacts_{8-100g}$ (n/min) (variance = 31.05). The second PC was composed of Acc_{total} (n/min) and $Dec_{2-1\ m/s/s}$ (n/min) (variance = 17.42). The third PC was composed of $Dist_{24-50km/h}$ (m/min) and Jumps (n/min) (variance = 13.47). The last PC was formed by HSR (m/min) (variance = 12.58). However, 67.6% of the variance in the 2nd half was explained by three PC. The first PC was composed of Dist (m/min), HSR (m/min) and $Dist_{Expl}$ (m/min) (variance = 34.42). The second PC was composed of Acc_{total} (n/min), $Dist_{0-6km/h}$ (m/min), $Impacts_{8-100g}$ (n/min) and Jumps (n/min) (variance = 19.25). The third PC was composed of $Dec_{10-6m/s/s}$ (n/min) (variance = 13.90) (Table 2).

Table 1. Match external workload demands extracted variables by halves

Variable	1st Half	2nd Half	Whole Match
Distance (m/min)	87.13 ± 21.7	72.87 ± 21.36	80.71 ± 21.09
High Speed Running (m/min)	2.36 ± 2.3	1.13 ± 1.87	1.94 ± 2.06
$Distance_{Explosive}$ (m/min)	12.68 ± 5.95	9.68 ± 6.2	11.82 ± 5.36
Acceleration $_{total}$ (n/min)	27.64 ± 5.64	27.27 ± 5.41	26.08 ± 3.95
Deceleration $_{2-1\ m/s/s}$ (n/min)	6.44 ± 5.61	6.05 ± 2.86	6.24 ± 4.26
Deceleration $_{10-6m/s/s}$ (n/min)	0.06 ± 0.13	0.04 ± 0.11	0.05 ± 0.12
Distance $_{0-6km/h}$ (m/min)	32.27 ± 7.2	34.1 ± 2.98	33.2 ± 5.34
Distance $_{24-50km/h}$ (m/min)	0.48 ± 0.65	0.24 ± 0.35	0.36 ± 0.4
Impacts $_{8-100g}$ (n/min)	25.74 ± 26.67	32.68 ± 41.4	29.21 ± 32.56
Jumps (n/min)	0.16 ± 0.13	0.39 ± 0.38	0.28 ± 0.21

Variability of data expressed using mean ±standard deviation.

Table 2. Futsal principal component analysis by halves and team with respective eigenvalue, variances and % variance explained.

Variables	1st Half				2nd Half			Whole Match		
PC	1	2	3	4	1	2	3	1	2	3
Eigenvalue	3.42	1.92	1.48	1.38	3.79	2.12	1.53	3.46	1.93	1.6
Variance	31.05	17.42	13.47	12.58	34.42	19.25	13.9	31.45	17.5	14.58
%Variance	31.05	48.47	61.95	74.53	34.42	53.67	67.57	31.45	48.95	63.53
Distance (m/min)	0.83				0.91			0.94		
High Speed Running (m/min)				0.68	0.65				NR	
$Distance_{Explosive}$ (m/min)	0.74				0.9			0.94		
Acceleration $_{total}$ (n/min)		0.87				0.81			0.74	
Deceleration $_{2\text{-}1\ m/s/s}$ (n/min)		0.85				NR			NR	
Deceleration $_{10\text{-}6m/s/s}$ (n/min)		NR					0.87			0.8
Distance $_{0\text{-}6km/h}$ (m/min)		NR				0.7			0.62	
Distance $_{24\text{-}50km/h}$ (m/min)			0.84			NR		0.62		
Impacts $_{8\text{-}100g}$ (n/min)	0.79					0.74			0.68	
Jumps (n/min)			-0.75			0.72			0.66	

NR= Non relevant. Variability of data expressed using mean ± standard deviation

Discussion

Analysis of the competition is decisive for proper training planning. Therefore, the main aim of the study was to analyze the principal components of an amateur futsal match external TL according to the halves of the game and considering the whole match. The main findings were: a) a combination of 3-4 PC from a total of 8 variables are required to explain futsal official match external TL; b) different PC were extracted when the analysis was carried out for the entire match, the 1st half and the 2nd half.

In the present study, the PCA analysis revealed that a combination of 3 PC was required during senior amateur futsal official games considering the whole match. In other sports such as soccer, a combination of several TL metrics have also been required to explain performance (i.e. team behavior) (Casamichana et al., 2019; Oliva-Lozano et al., 2020; Pino-Ortega et al., 2020). For example, in soccer Casamichana et al. (2019) found that 3 PC are required during professional football game formats, and Oliva Lozano et al., (Oliva-Lozano et al., 2020) found that four PC are required to explain performance. Similarly, in other sports such as basketball, Pino-Ortega et al., (2020) found that 3 PC were extracted from a total of 252 variables. Therefore, for team sports analysis, a combination of 3-4 PC have been needed to explain performance, at least, when extraction criteria were set at an eigenvalue of greater than one, and intensity training load metrics with PC "loadings" above 0.6 or 0.7 were deemed to possess well-defined relationships with the extracted PC.

In the present study, 63.5% of the whole match behavior was explained by three PC formed by eight variables: Dist (m/min), HSR (m/min), DistExpl (m/min), Acctotal (n/min), Dec2-1 m/s/s (n/min), Dist24-50km/h (m/min), impacts8-100g (n/min) and Jumps (n/min). In basketball, Pino-Ortega et al., (2020) found that accelerations, landings, relative distance, takeoffs, and landings formed three PCs. Several similar characteristics between these sports (i.e. futsal and basketball) such as game space may lead to PC being composed of some coincident variables related to high-intensity efforts such as accelerations and jumps. However, other different internal logic constraints (Parlebas, 2002) such as the location of the goal, may explain that PC is composed of some different variables such as takeoffs and landings, unlike futsal. However, in soccer with greater space in comparison with the aforementioned sports, Oliva-Lozano et al. (2020) found that both high-intensity variables (i.e. accelerations and high-speed distance covered) and other variables related to lower intensities (i.e. total distance, Dist0-6, Dist21-24) explained more of game external TL. This could be due to the differences in the structural traits of the sports such as the relative space per player. However, unlike basketball, soccer and futsal are not explained by takeoffs or landings, at least as a PC. Therefore, it seems that internal logic constraints, such as game space and goal location influence PCA. This finding is consistent with studies that explained that in those sports in which more distance is covered (more aerobic sports) (e.g. soccer), PC might be explained with some variables related with fewer intensity efforts, while in those sports with less total distance covered and more distance covered at high-intensity (sports with a higher anaerobic component) (Agras et al., 2016), high intensity variables explain game behavior. However, these results do not coincide with Casamichana et al., (2019) who looked for PC in different area per player (from 21 m to 310 m) during possession games, small-sided games and official matches, and found that in general, the same PC explain training load (1st PC = distance, Acc, Dec, average metabolic power and high metabolic load distance (% variance = 39-44); 2nd PC = high speed running, sprint and Vmax (% variance = 22-26); 3th PC = dynamic stress load and impacts (% variance = 14-20)). So, although PC might be influenced by the internal logic of the game, further studies are needed.

Team behavior is influenced by the team´s objectives (Schmidt, O´ Brien, & Sysko, 1999) which may change over time due to the match status, or other factors related to fatigue (Pino-Ortega et al., 2019). In a systematic review of futsal game demands carried out by Gioldasis (2016), it was found that the total distance travelled, the number of high-intensity actions and the maximum heart rate are lower in the second part compared to the first. Additionally, in those sports divided into four quarters such has hockey and basketball, a different performance was found. For example, in hockey, McGuinness et al. (McGuinness, Malone, Petrakos, & Collins, 2019) found that the time spent >85% HRpeak decreased significantly across the quarters ($p = 0.04$, $\eta 2 = 0.09$, Small). In the same way, Morencos, Casamichana, Torres, Haro, & Rodas (2019) compare the kinematic demands on sixteen international women field hockey players during European Championship matches according to the quarters in the game (Q1, Q2, Q3, Q4). In basketball, Pino-Ortega et al. (2019) discovered a significant decrease in the relative distance traveled ($P < 0.01$) in the last quarter of the match. In addition, the variables related to intensity were greater in the Q1 than in the rest of the game, with a larger effect size found between the first and second part in DR (relative distance) and in high intensity running (HIR) (DR: $p < 0.05$, $d = -0.78$ moderate effect; HIR%: $p < 0.05$, $d = -0.31$ small effect). These results could be due to physiological fatigue related to lactate concentration at rest and an increase in match stoppages (fouls, downtime, etc.) that influence game pace (Pino-Ortega et al., 2019). So, we hypothesized that different team behavior shown over different time halves could influence PC. Therefore, the aim of this study was to analyze PCA in each match half. The results showed that different PC explain game behavior in the 1st half than in the 2nd half in futsal senior official games. Specifically, 74.5% of the 1st half was explained by four PC composed of Dist (m/min), DistExpl (m/min), Impacts8-100g (n/min), Acctotal (n/min), Dec2-1 m/s/s (n/min), Dist24-50km/h (m/min), Jumps (n/min) and HSR (m/min) variables. However, 67.6% of the 2nd half was explained by three PC from Dist (m/min), HSR (m/min), DistExpl (m/min), Acctotal (n/min), Dist0-6km/h (m/min), Impacts8-100g (n/min), Jumps (n/min) and Dec10-6m/s/s (n/min) variables. Coaches and researchers should assess teams' and players' behavior based on different PC during different halves in futsal. Given that the investigation only analyzed one match, it is recommended that future research assess more matches during a whole tournament or over a season. In addition, since PCA has been related to performance, and because the external training load varies considerably according to the characteristics of each team sport (Agras et al., 2016; Palucci Vieira, Carling, Barbieri, Aquino, Santiago, 2019; Romero-Moraleda, Morencos, Torres, & Casamichana, 2020), training task (Halouani, Chtourou, Gabbettt, Chaouachi, & Chamari, 2014) and competitive level of the players (Álvarez, D´ottavio, vera, & Castagna, 2009), the PCA should be assessed in each team sport, in different training tasks, and with players of different ages.

Practical applications

Three main practical applications can be highlighted from the results found:

- The assessment of amateur futsal players performance could be carried out through the following variables: Distance (m/min), $Distance_{0\text{-}6km/h}$ (m/min), HSR (m/min), $Distance_{Explosive}$ (m/min), $Distance_{24\text{-}50km/h}$ (m/min), $Acceleration_{total}$ (n/min) $Deceleration_{2\text{-}1\ m/s/s}$ (n/min), $Deceleration_{10\text{-}6m/s/s}$ (n/min), $Impacts_{8\text{-}100g}$ (n/min).
- Considering the characteristics of the aforementioned variables, strength and conditioning coaches may design training tasks that induce high-intensity actions in combination with high degree of aerobic endurance during futsal training.
- In order to maintain those efforts throughout the match, strength and conditioning coaches should design training tasks to develop strength and power resistance allowing the repetition of these actions during competition with lower indices of fatigue. Additionally, team staff must devise players substitution strategies during the match, considering team and individual physical and physiological behavior.

Conclusions

A combination of 3-4 PC from a total of 8 variables was required to explain senior futsal official games. While several variables such as impacts, decelerations and distance covered at >24 km/h explained the players´ behavior during the 1st half, the cumulative fatigue could justify the detriment of the importance of these intensity-based efforts and the increment of the distance covered at lower intensities on the 2nd half.

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