COMPARISON OF EXTERNAL LOAD DURING PRE-MATCH WARM-UP AMONG DIFFERENT AGE CATEGORIES FROM THE SAME FOOTBALL PROFESSIONAL CLUB

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Abstract:

The aim of the present study was to compare the external load (EL) of the football pre-match warm-up (WU) in absolute terms and as a percentage (%) of the individual match demands. A total of 96 football players from different age categories participated in the study: professional (PRO, n=26), reserve (RES, n=22), under-21 (U21, n=28) and U18 (n=20) teams. Eleven EL variables were obtained through global positioning system devices. The results show that there are differences among teams in total duration, total distance, number of accelerations and decelerations, acceleration load, distance covered at different speed ranges and the maximum velocity, both expressed absolutely and relative to the match demands. The EL of the WU represents a variable percentage depending on a particular variable with respect to the match, ranging from ≈5% for high-speed running or very high-speed running to ≈20% for acceleration-load. The conclusions were: 1) the WU load represents an important part of the EL on players in soccer matches, and 2) the PRO team presented a lower EL in most of the variables, being consistent in both absolute and relative terms to the match demand. The strength and conditioning coaches must be cautious not to cause fatigue in the players while guaranteeing an adequate set-up to dispute the match.

Keywords: *GPS, soccer, team sport, elite, training load, age-group*

Introduction

The warm-up (WU) is a protocol specifically undertaken to prepare athletes for the onset of subsequent physical tasks (McCrary, Ackermann, & Halaki, 2015) that can be a training session or a competition. It aims at increasing neural activation and raising core and skeletal muscle temperature (Zois, Bishop, & Aughey, 2015) in order to increase blood flow and optimize metabolic responses during exercise (e.g., faster oxygen uptake kinetics) (Maturana, Peyrard, Temesi, Millet, & Murias, 2018). Several researches have shown that a well-structured active warm-up can increase performance and reduce the risk of injuries (Lovell, Midgley, Barrett Carter, & Small, 2013). However, if the exercise volume and intensity are too high, glycogen stores can be reduced and body temperature rises excessively, with consequent performance impairment (Gregson, Batterham, Drust, & Cable, 2005).

Concerning football, usually, the WU has been composed of activities such as: static and dynamic stretching, injury-preventive neuromuscular activities, post activation potentiating based-exercises and high-intensity short duration WU (Hammami, Zois, Slimani, Russel, & Bouhlel, 2018), among others. Nowadays, it is still not clear which method may be the best, even if some of them might be better than the others. What is clear is that the use of specific football movements has positive effects on the performance (Taher & Parnow, 2017).

Regarding the duration and the intensity, it is not clear how the pre-match WU (PMWU) should be. In previous studies, there are WU routines lasting from five minutes (Carvalho, et al., 2012) to 35 minutes (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004), combining high-intensity (Zois, et al., 2015) and lower intensity preparatory exercises (Anderson, Landers, & Wallman, 2014). Concerning the duration, Yanci and collegues (2019) found that the sprint performance of the players was better after a 8-minute PMWU than after a 25-minute one. On the other hand, the systematic review by Silva and collegues (2018) revealed that PMWU time must be between 10 and 15 minutes, increasing the intensity progressively to optimize explosive performance. This increment of the intensity during PMWU was due to the higher number of accelerations and decelerations per minute in professional futsal teams (Silva, Travassos, Gonçalves, Brito, & Abade, 2020).

The inclusion of Global Positioning System (GPS) technology in the training process has made it possible to obtain objective external load (EL) information from training tasks (Martín-García, et al., 2020), sessions, training weeks (Martín-García, Gómez-Díaz, Bradley, Morera, & Casamichana, 2018), or longer periods of time such as a whole season (Anderson, et al., 2016). Recently, this technology has been applied in the study of the PMWU period of football matches, comparing the physical load during the PMWU with that recorded during the whole match (Williams, Jaskowak, & Williams, 2019). This research concludes that a PMWU amounts between 22% (≈2,000 m of TD for the soccer players) and 27% of external match load, including values of ≈25% in distance covered at sprinting (SPR).

On the other hand, it has been seen that the physical performance of a match is very different in every age and league. Senior professionals play the match at higher intensity (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010), partly because they have higher levels of physical fitness than young players. Relativizing the PMWU loads using the match load as a reference will allow more meaningful comparison of the different age groups, and provide a better understanding about their respective pre-match preparation.

Accordingly, the aim of this study was to compare the absolute and relative (with reference to the individual match demands) EL during PMWU in official matches between four teams of different age categories belonging to the same professional club. The results will allow to know if there is a progression in the absolute loads to which players are exposed in different age categories, in addition to knowing if all the EL variables are requested in the same magnitude with respect to the match demands.

Methods

Participants

The players who participated in this study were 96 players from different age categories of the same professional Spanish club: professional team (PRO, n=26; age: 25.1 ±4.1 years; stature: 180.2 ±6.4 cm; body mass: 74.7±6.6 kg), reserve team (RES; n=22; age: 21.2 ±1.6 years; stature: 171.4 ±38.2 cm; body mass: 72.7 ±5.9 kg), under-21 team (U21; n=28; age: 19.7 ±1.1 years; stature: 178.2 ±5.4 cm; body mass: 71.4 ±6.0 kg) and under-18 team (U18; n=20; age: 18.0 ±0.6 years; stature: 173.6 ±8.2 cm; body mass: 71.8 ±5.9 kg). The referred professional team was playing in the Spanish First League (La Liga) and regularly participated in international competitions (e.g. UEFA Europa League). The sample size was calculated with the independent power analysis program G*Power (version 3.1.9.7 for Windows, Institut für Experimentelle Psychologie, Düsseldorf, Germany). In a statistical ANOVA test for where four groups are compared, an effect size of 0.50, a probability of error α of 0.05, and a power of 0.95 (1-β) (Faul, Erdfelder, Lang, & Buchner, 2007), the total estimated sample was n=76 players (less than the 96 players recorded in the present study). The data arose as a condition of employment for the players, who were assessed on a daily basis. The club gave consent to use the information, the players gave informed consent before participating, the players' identities were anonymized and the Ethics Committee reported favorably (code: M10-2024-124).

Measures

All PMWU EL demands were monitored using GPS units. A total of eleven GPS variables were measured both in the PMWU and during the match. The variables analyzed were the total duration (minutes), total distance covered (TD, m), distance covered at moderate speed running (MSR: >14 $km \cdot h^{-1}$, m), distance covered at high speed running (HSR: >18 $km \cdot h^{-1}$, m), distance covered at very high speed running (VHSR: >21 $km \cdot h^{-1}$, m), distance covered at sprinting (SPR: >24 $km \cdot h^{-1}$, m), the acceleration load (Aload, AU), the player load (PL, AU), the number of moderate and high-intensity accelerations (ACC: >2 $m \cdot s^{-2}$, n) and decelerations (DEC: <-2 $m \cdot s^{-2}$, n), and the maximum velocity reached (Vmax: $km \cdot h^{-1}$). The intensity thresholds used have been established based on previous studies (Guridi, Catellano, & Echezarra 2021) . The velocity dwell time (i.e., minimum effort duration) was 0.5 second, the acceleration dwell time was 0.1 second and the minimum acceleration interval duration was 0.8 second. The configuration of the devices, although not usually stated in the studies, is key to interpret the data correctly (Torres-Ronda, Beanland, Whitehead, Sweeting, & Clubb, 2022).

The variable Aload is calculated by summing all accelerations and decelerations in positive, and this variable provided an indication of the total acceleration requirements of the athlete, irrespective of velocity. Previous research studies have shown an inter-unit coefficient of variation of 2-3% (Delaney, Cummins, Thornton, & Duthie, 2018) and these are lower than typically seen between devices using the traditional effort-detection-based approach to acceleration assessment (Delaney, et al., 2018). PL is an indicator based on the combined accelerations made in three planes of movement. Previous research on this indicator had reported high intra- and inter-device reliability (Boyd, Ball, & Aughey, 2011), and it had been shown to be a valid way of monitoring training load in soccer players (Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013).

The number of satellites used to infer GPS signal quality, horizontal dilution of precision and the average of the GNSS quality were for the PRO: 12.1±0.9 satellites, 0.9±0.3 and 65.3±8.5%; for the RES: 11.6±0.9 satellites, 0.9±0.3 and 67.1±5.3%; for the U21: 11.7±0.5 satellites, 0.8±0.1 and 68.6±4.7%; and for the U18: 11.9±0.1 satellites, 0.8±0.1 and 71.1±4.5%, respectively.

Procedures

The study was conducted in 2019-2020 competitive season. Data collection was carried out during the season, in competitive microcycles, keeping environmental conditions such as temperature and humidity similar in all records. The data were collected by experienced physical preparation managers. The weekly training routines and competitive matches were the usual competitive training microcycles carried out during the whole season. The external training load was collected using GPS devices (Vector S7 for PRO and RES and Vector X7 for U21 and U18, both by Catapult). The players were familiar with the use of GPS, as it was part of their daily routine for TL monitoring. Players wore a GPS device from the beginning of the WU until the end of the match. The GPS device was fitted to the upper back (i.e., between the shoulder blades) of each player using an adjustable neoprene harness. After each game, the data was extracted to a computer and analysed using Catapult OpenField v2.4. A total of 719 individual GPS files from PMWU data were analyzed, with the following distribution per team: PRO=106, RES=155, U21=263 and U18=195 GPS files, with an average of 4.7 ±2.9 (min=1 and max=12) observations per player. All players had to undertake at least one complete PMWU to participate in the study. Players who did not meet this criterion were withdrawn from the study.

Furthermore, the EL of the match completed by each player was calculated to compare with the demand of the PMWU. The match demand was estimated for the players who did not complete a match in the study period: a) for players who played less than 70 minutes the average EL of full matches of the player's position was taken into account and b) for players who played more than 70 minutes the EL was used to calculate the EL they would have in 94 minutes of the game.

The value of each PMWU was expressed in absolute values and relative to the mean EL registered during competitive matches:

(mean training session EL x 100) /
mean competitive-match EL.

Statistical analyses

The descriptive statistics were calculated and reported as mean and standard deviation (±SD) for each age category on each variable. Both, absolute and relative (with reference to the individual match) values were used for analysis. While the dependent variables were total duration and the 10 EL measures, independent variables were the different teams studied. The differences between age category groups in all measured variables were examined using analysis of variance (ANOVA) for independent samples. *Post-hoc* analyses were performed using Bonferroni's honestly significant difference test. Descriptive statistics for the outcome measures were calculated using mean, standard deviations and confidence interval at 95%. Cohen's d effect size was used for pairwise comparisons. Thresholds for effect size (ES) statistics were <0.2, trivial; <0.6, small; <1.2, moderate; <2.0, large; and ≥2.0, very large (Hopkins, Marshall, Batterham, & Hanin, 2009). All data analyses were carried out using *Excel* and the statistical analysis software *JASP version 0.9.2* (University of Amsterdam, https://jasp-stats.org/). The level of significance was set at p<.05.

Results

Absolute pre-match WU load

Table 1 presents the absolute values obtained in the PMWU across variables. The total duration was higher for PRO, U21 and U18 with respect to RES team (ES: 1.0-3.6; p<.001), while PRO and U18 warmed up for longer time than U21 (ES: 0.5-2.2; p<.001). Finally, U18 warmed up for longer time than PRO (ES: 1.5; p<.001).

The RES team obtained a higher accumulated load than PRO, U21 and U18 in the MSR and DEC variables (ES: 0.7-2.5; p<.001). U21 obtained a higher cumulative load than PRO, RES and U18 in the variables VHRS (ES: 1.0-1.3; p<.001), SPR (ES: 1.3-1.7; p<.001) and Vmax (ES: 0.9-1.8; p<.001). In addition, the group U18 obtained a higher cumulative load than PRO, RES and U21 in the variables total duration, PL and Aload (ES: 0.4-3.6; p<.001).

In the variables TD, MSR, HRS, ACC and DEC, the teams RES, U21 and U18 accumulated greater EL than PRO (ES: 0.3-2.5; p<.001). In the variable TD, the RES and U18 teams covered more distance than U21 (ES: 0.3-0.4; p<.001), and the opposite occurred in the MSR and HSR variables, where the U21 team covered more distance than U18 (ES: 0.7-1.0; p<.001). In the HSR variable, it can also be seen that the RES team covered more distance than U18 (ES: 0.9; p<.001). In the variables SPR and Vmax, the PRO and U18 teams obtained a greater accumulated load than RES (ES: 0.4-0.9; p<.001). In the variable Vmax it can also be seen that the PRO group achieved higher speeds than U18 (ES: 0.4; p<.001). In the variable PL, U21 obtained grater load than RES team (ES: 0.4; p<.001). Finally, in the DEC variable, the U18 team obtained higher number of actions than U21 (ES: 0.4; p<.001).

Figure 1 shows the significant difference between the four teams in the MSR (m) variable. All the teams covered more distance at MSR than the PRO (ES: 0.9-2.5; p<.001). Furthermore, the RES team covered significantly more distance at MSR than the U21 team (ES: 0.9; p<.001) and U18 (ES: 1.3; p<.001). Finally, the U21 team covered significantly more distance at MSR than the U18 (ES: 0.7; p<.001).

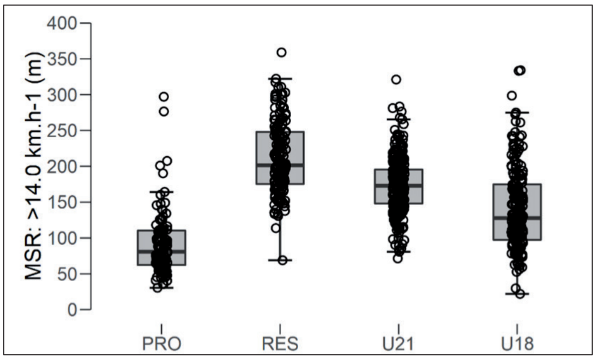

Figure 1. Comparison of distance covered at moderate speed running (MSR: >14km·h^{-1}) (m) during the pre-match warm-up between different teams in absolute terms.

Relative PMWU load

Table 2 presents the values obtained in the PMWU across variables according to the percentage of the individual match demands. The RES team obtained a higher accumulated load than PRO, U21 and U18 in the MSR (ES: 0.6-2.6; p<.001) and DEC variables (ES: 0.9-1.7; p<.001). U21 covered more distance than PRO, RES and U18 in the variables VHRS (ES: 1.0-1.1; p<.001), SPR (ES: 1.1-1.4; p<.001) and reached higher Vmax (ES: 0.8-2.0; p<.001). In addition, the group U18 obtained a higher cumulative load than PRO, RES and U21 in the variables total duration (ES: 1.4-3.8; p<.001), PL (ES: 0.3-0.7; p<.001), and Aload (ES: 1.0-1.2; p<.001).

In the variables TD, MSR, HRS, ACC and DEC, the teams RES, U21 and U18 developed greater EL than PRO (ES: 0.5-2.6; p<.001). In the total duration variable, PRO obtained a higher volume than RES (ES: 1.8; p<.001) and U21 (ES: 0.6; p<.001), while U21 accumulated longer time than RES (ES: 1.1; p<.001). In the variable TD, the U18 team covered more distance than U21 (ES: 0.4; p<.001). In the MSR and HSR variables, the U21 team covered more distance than U18 (ES: 0.8-1.0; p<.001). In the HSR variable, it can also be seen that the RES team covered more distance than U18 (ES: 0.9; p<.001). In the variables SPR and Vmax, the PRO and U18 teams obtained a greater accumulated load and reached higher Vmax than RES (ES: 0.7-1.2; p<.001). In the variable Vmax it can also be seen that the PRO group achieved higher speeds than U18 (ES: 0.3; p=.037). In the variable PL, U21 obtained grater load than RES team (ES: 0.3; p=0.007). Finally, in the ACC variable, the RES team obtained higher number of actions than U21 and U18 (ES: 0.9-1.2; p<.001).

Discussion and conclusions

The main purpose of this study was to compare the EL of the PMWU in absolute terms and as a percentage of the individual match demands in football teams of different ages belonging to an elite professional football club. The main findings of the study refer to the fact that the PRO team presents a lower level of EL in most of the variables studied, and these differences were consistent both when the external demand for PMWU was compared in absolute terms and relative to the match demands. The relative load (%) of some variables with respect to the match demands exceeded 20% of the match load (e.g., Aload), which should be assessed by the strength and conditioning coach to prevent fatigue in the players while ensuring an adequate condition of them to dispute the match.

Although PMWU has traditionally been approached as an important element in preventing football player's injuries (Soligard, et al., 2009), very little information exists regarding the EL in soccer players during PMWU. Regarding the duration, it is not very clear how the PMWU should be. In previous studies, there are reports of PMWU between five minutes (Carvalho, et al., 2012) and 39 minutes (Williams, et al., 2019). Other study (Yanci, et al., 2019) has suggested that although all protocols (warm-up duration of 25, 15 and 8 min) significantly improved the feeling of players being prepared to play the game, only the shortest improved the acceleration ability of the soccer players. In the present study, the PMWU durations ranged between ≈18-25 min, there being significant differences across all the teams. Although the club has established a protocol to carry out the PMWU, sometimes due to the dynamics proposed by the coach regarding the duration of activities and breaks, players' requests to shorten or lengthen preparatory tasks, coaching pre-instructions delaying the start of PMWU more than desired, or weather aspects (e.g., hot environment that invites to reduce the duration of the

Table 1. Comparison of external pre-match warm-up load (mean and standard deviation) between different teams in absolute terms

Teams	Total duration (minutes)	TD (m)	MSR (m)	HSR (m)	VHSR (m)	SPR (m)	Vmax (km·h^{-1})	PL (AU)	Aload (AU)	ACC (n)	DEC (n)
PRO	21.2±3.2^{bc}	1,388.4±183.8	90.9±44.4	39.5±18.9	23.7±11.9	10.5±8.4^{b}	25.5±2.3^{bd}	180.5±26.0	534.1±60.5	16.0±4.7	10.3±4.4
RES	17.3±0.6	1,600.2±144.2^{ac}	212.2±50.1^{acd}	74.7±30.3^{ad}	25.3±22.3	5.1±11.2	23.6±2.0	174.5±24.2	534.4±50.7	21.8±6.5^{a}	19.9±7.0^{acd}
U21	19.5±2.4^{b}	1,546.1±170.4^{a}	174.0±38.8^{ad}	73.6±23.8^{ad}	45.9±18.3^{abd}	29.3±15.7^{abd}	27.5±2.4^{abd}	185.8±27.4^{b}	539.6±66.9	22.5±5.0^{a}	14.1±43.0^{a}
U18	25.6±2.6^{abc}	1,612.6±197.8^{ac}	140.4±57.3^{a}	48.1±26.5^{a}	24.1±14.7	9.5±9.3^{b}	24.5±2.6^{b}	198.6±29.5^{abc}	620.5±78.7^{abc}	21.3±5.7^{a}	16.0±4.9^{ac}
F(p)	331.534 (<0.001)	42.603 (<0.001)	154.675 (<0.001)	78.182 (<0.001)	83.395 (<0.001)	169.206 (<0.001)	113.236 (<0.001)	24.734 (<0.001)	75.268 (<0.001)	36.576 (<0.001)	81.162 (<0.001)
ES	PRO-RES: 1.7 PRO-U21: -0.5 PRO-U18: 1.5 RES-U21: 1.0 RES-U18: 3.6 U21-U18: 2.2	PRO-RES: -1.3 PRO-U21: -0.9 PRO-U18: -1.2 RES-U21: 0.3 RES-U18: -0.1 U21-U18: -0.4	PRO-RES: -2.5 PRO-U21: -2.1 PRO-U18: -0.9 RES-U21: 0.9 RES-U18: 1.3 U21-U18: 0.7	PRO-RES: -1.3 PRO-U21: -1.5 PRO-U18: -0.4 RES-U21: 0.0 RES-U18: 1.0 U21-U18: 1.0	PRO-RES: -0.1 PRO-U21: -1.3 PRO-U18: -0.0 RES-U21: -1.0 RES-U18: 0.1 U21-U18: 1.3	PRO-RES: 0.5 PRO-U21: -1.3 PRO-U18: 0.1 RES-U21: -1.7 RES-U18: -0.45 U21-U18: 1.5	PRO-RES: 0.9 PRO-U21: -0.9 PRO-U18: 0.4 RES-U21: -1.8 RES-U18: 0.4 U21-U18: 1.3	PRO-RES: 0.2 PRO-U21: -0.2 PRO-U18: -0.6 RES-U21: -0.4 RES-U18: - 0.9 U21-U18: -0.5	PRO-RES: -0.0 PRO-U21: -0.1 PRO-U18: -1.2 RES-U21: -0.1 RES-U18: -1.3 U21-U18: -1.1	PRO-RES: -1.0 PRO-U21: -1.3 PRO-U18: -1.0 RES-U21: -0.1 RES-U18: 0.1 U21-U18: 0.2	PRO-RES: -1.6 PRO-U21: -0.9 PRO-U18: -1.2 RES-U21: 1.1 RES-U18: 0.7 U21-U18: -0.4

Note: TD is total distance; MSR is distance covered at moderate speed running (>14 km·h^{-1}); HSR is distance covered at high speed running (>18 km·h^{-1}); VHSR is distance covered at very high speed running (>21 km·h^{-1}); SPR is distance covered at sprinting (>24 km·h^{-1}); Vmax is maximum velocity reached (km·h^{-1}); PL is the player load; Aload is the acceleration load; ACC is the number of moderate and high intensity accelerations (>2 m·s^{-2}); DEC is the number of moderate and high intensity deceleration (<-2 m·s^{-2}); a>PRO; b>RES; c>U21; d>U18.

Table 2. Comparison of external pre-match warm-up load (mean and standard deviation) between different teams in percentage (%) of the individual match demands

Teams	Total duration	TD	MSR	HSR	VHSR	SPR	Vmax	PL	Aload	ACC	DEC
PRO	23.0±3.7^{bc}	13.3±1.8	3.8±1.8	3.9±2.1	5.0±3.0	6.3±6.2^{b}	80.2±7.8^{bd}	17.2±2.5	18.5±2.0	13.8±4.5	9.0±4.0
RES	18.4±1.0	15.0±1.2^{a}	8.8±2.0^{acd}	7.8±3.0^{ad}	5.2±3.9	2.2±4.6	72.3±5.6	17.0±2.1	18.1±1.8	19.8±5.6^{ad}	17.7±5.8^{acd}
U21	21.0±3.0^{b}	14.6±1.7^{a}	7.7±1.9^{ad}	8.3±3.3^{ad}	11.4±6.3^{abd}	22.3±17.4^{abd}	86.1±7.4^{abd}	17.8±2.6^{b}	18.4±2.3	19.0±4.2^{ad}	12.3±3.6^{a}
U18	27.7±3.2^{abc}	15.4±2.0^{ac}	6.1±2.4^{a}	5.2±2.8^{a}	6.0±4.0	7.4±8.1^{b}	77.7±8.3^{b}	18.6±2.5^{abc}	21.0±2.7^{abc}	17.4±4.5^{a}	13.2±3.7^{a}
F(p)	343.791 (<0.001)	34.966 (<0.001)	153.635 (<0.001)	80.934 (<0.001)	83.433 (<0.001)	120.732 (<0.001)	122.577 (<0.001)	14.558 (<0.001)	65.883 (<0.001)	41.299 (<0.001)	93.644 (<0.001)
ES	PRO-RES: 1.8 PRO-U21: 0.6 PRO-U18: -1.4 RES-U21: -1.1 RES-U18: -3.8 U21-U18: -2.2	PRO-RES: -1.1 PRO-U21: -0.8 PRO-U18: -1.1 RES-U21: 0.2 RES-U18: -0.2 U21-U18: -0.4	PRO-RES: -2.6 PRO-U21: -2.1 PRO-U18: -1.0 RES-U21: 0.6 RES-U18: 1.2 U21-U18: 0.8	PRO-RES: -1.5 PRO-U21: -1.5 PRO-U18: -0.5 RES-U21: -0.2 RES-U18: 0.9 U21-U18: 1.0	PRO-RES: -0.1 PRO-U21: -1.1 PRO-U18: -0.3 RES-U21: -1.1 RES-U18: -0.2 U21-U18: -1.0	PRO-RES: 0.8 PRO-U21: -1.1 PRO-U18: -0.1 RES-U21: -1.4 RES-U18: -0.8 U21-U18: 1.1	PRO-RES: 1.2 PRO-U21: -0.8 PRO-U18: 0.3 RES-U21: -2.0 RES-U18: -0.7 U21-U18: 1.1	PRO-RES: 0.1 PRO-U21: -0.2 PRO-U18: -0.6 RES-U21: -0.3 RES-U18: -0.7 U21-U18: -0.3	PRO-RES: 0.2 PRO-U21: 0.0 PRO-U18: -1.0 RES-U21: -0.1 RES-U18: -1.2 U21-U18: -1.1	PRO-RES: -1.2 PRO-U21: -1.2 PRO-U18: -0.8 RES-U21: 0.2 RES-U18: 0.5 U21-U18: 0.4	PRO-RES: -1.7 PRO-U21: -0.9 PRO-U18: -1.1 RES-U21: 1.2 RES-U18: 0.9 U21-U18: -0.2

Note: TD is total distance; MSR is distance covered at moderate speed running (>14 km·h^{-1}); HSR is distance covered at high speed running (>18 km·h^{-1}); VHSR is distance covered at very high speed running (>21 km·h^{-1}); SPR is distance covered at sprinting (>24 km·h^{-1}); Vmax is maximum velocity reached (km·h^{-1}); PL is the player load; Aload is the acceleration load; ACC is the number of moderate and high intensity accelerations (>2 m·s^{-2}); DEC is the number of moderate and high intensity deceleration (<-2 m·s^{-2}); a>PRO; b>RES; c>U21; d>U18.

PMWU or cold environment that requires a longer PMWU) may be the reason for this variability.

In absolute terms, in the current study, we found lower values of TD and SPR with respect to the study of Williams et al. (2019). These authors found that the PMWU involved 2,000 m of TD for the soccer players, representing more than 20% of the TD in the match, reaching values of more than 25% in SPR. The strategies used by the teams during the PMWU are variable and of different duration, which could explain these differences, since they spent more than 39 minutes of PMWU in the referred study (Williams, et al., 2019). In contrast, compared to the English Championship players investigated by Hills et al. (2020), in our study teams had very similar absolute TD (≈1,500 m) and ACC values and higher MSR, HSR, SPR, PL and DEC values at shorter PMWU durations. Moreover, in a previous study with futsal players (Silva, et al., 2020), the players covered shorter absolute TD in the warm-up (≈1000 m). It is necessary to consider that the court size in a futsal match is smaller than in soccer match (for instance in total distance), since the duration of the match is shorter.

In the comparison of the analysed teams, the results show that each team prioritizes a type of movement, obtaining higher values in certain EL parameters. The PRO team presents the lowest values in many of the EL variables studied (e.g., TD, HSR or ACC), while the U18 obtained the highest values in the global EL variables (e.g., PL and Aload) and U21 in the high-speed variables (i.e., VHSR and SPR). Probably as a habitual consequence of congested calendar periods or a better knowledge of the individual needs of professional players, they try to make the performance carried out as efficient as possible. On the other hand, the variability among teams may be due to the different dynamics proposed by the physical condition coaches. It may also be conditioned by contextual factors (e.g., weather, time available, proximity between facilities), so it could be interesting to pay special attention to the said activity with the double objective of optimizing while not compromising performance in a competition. As it is known (Hills, et al. 2020), a well-designed warm-up routines could optimize match performance and the duration of the warm-up could be important to be accounted for (Yanci, et al., 2019). In this sense, clubs should regulate this type of intervention between the teams under their responsibility, trying to optimize them.

The comparison of demands expressed in terms of the percentage of the match demand has been an analytical strategy used in recent years. Thus, the intensity of the training tasks (Martín-García, et al., 2020), the load of different training sessions of a microcycle (Martín-García, et al., 2018) or the accumulated load of the training sessions have been analysed under this perspective making comparisons of positions (Baptista, Johansen, Figueiredo, Rebelo, & Pettersen, 2019) or by differentiating between starters and non-starters (Stevens, de Ruiter, Twisk, Savelsbergh, & Beek, 2017). In our study, the differences between the teams are hardly modified when the values are expressed in absolute terms or according to the match demands (%). This may be because the competition demands do not differ too much between teams of different age groups in the adulthood (Dellal & Wong, 2013), a scenario that differs when players are younger (Buchheit, et al., 2010). The EL of the PMWU represents a variable percentage depending on the external variable chosen with respect to the match, ranging from ≈5% for distances covered at high speed (HSR: >18 $km{\cdot}h^{-1}$ and VHSR: >21 $km{\cdot}h^{-1}$) to ≈20% (e.g., SPR for U21 or Aload for U18). It seems interesting that load variables such as PL, Aload, ACC and DEC represent a load of ≈15-20% with respect to the match demands. Instead, high-speed variables such as HSR, VHSR and SPR represent around ≈5-10%, although the average of the percentage of the variables was around 15% of the match load. Systematic and efficient training should ensure that players are prepared to compete, reducing the adverse effects of possible previous fatigue.

Sprint actions are one of the most frequent mechanisms of hamstring injury (Schuermans, Van Tiggelen, Palmans, Danneels, & Witvrouw, 2017). Although the occurrence of near-to-maximal speed-running bouts in elite soccer are not so frequent (Buchheit, Simpson, Hader, & Lacome, 2021), several studies have appeared in recent years advocating the need to manage this type of high intensity action on a weekly and monthly basis, reducing the likelihood of injury through stable over time and moderate stimulation (Colby, et al., 2018). However, to date, there is only one investigation that shows the maximum speed reached by football players during PMWU in absolute terms (Hills, et al., 2020). The peak speed achieved in the teams studied were higher (23.6-27.5 $km{\cdot}h^{-1}$) than (19.5 $km{\cdot}h^{-1}$) in the previous research study (Hills, et al., 2020). However, there is no information regarding the maximum speed relative achieved in PMWU in respect to the match demands. In this regard, the present study shows that the maximum speed reached by players during PMWU is between 70 and 90% of the individual maximum speed. Since match players reach values close to their individual maximum speed (Sparks, Coetzee, & Gabbett, 2017) and based on the high levels of muscle activation required in a sprint action (Ross, Leveritt, & Riek, 2001), it seems necessary to reach a high percentage of the individual maximum speed during the PMWU activity. The importance of preparing the player for this type of effort is mainly due to the fact that it is not known if the first action at the start of the match will require this type of activity carried out at maximum speed, given that the first 15 minutes of matches are usually the most demanding (Bradley, et al., 2009).

Nowadays, although there is the possibility of using GPS devices during professional football matches, many teams monitor their players' activity through video-tracking systems. These video-tracking systems do not provide information on the activity of players during the PMWU. Taking into account that there are variables with PMWU loads close to 5-20% of a match effort, it seems interesting to register this load in order to estimate the values accumulated by the player during the microcycle, mesocycle or for the calculation of some training load indicators such as training monotony or strain (Clemente, et al., 2020) or the assessment of week-to-week changes in training load aside from a total training load (Gabbet, 2016).

Among the main limitations of the study, we can state that no internal load variable of the players was included. This would have allowed a better understanding of how external demand provokes a particular internal response in each player. Furthermore, having a detailed analysis of the positions would have made it possible to assess whether the activities or tasks proposed in the PMWU provides appropriate stimulation for players in different positions. Future research should include proposals to overcome the limitations of this study.

The main conclusion of the study is that during the PMWU there are some variables with loads close to 15-20% of the match load. For this reason, it seems interesting to take into account this EL in order to estimate the values accumulated by the player during the workload monitoring cycle. On the other hand, the variables that are most activated during the PMWU are PL and Aload, unlike the VHSR and SPR, which are the least demanded, so they never reach maximum speed. Finally, the PRO team presents the lowest values in many of the EL variables studied (e.g. TD, HSR or ACC), perhaps because experience allows them to fine-tune the requirements and that the warming-up is effectively carried out with a minimum energy cost.

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