Accelerometry-based variables in professional soccer players: comparisons between periods of the season and playing positions

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ABSTRACT: The aim of this study was to provide reference data of variation in external training loads for weekly periods within the annual season. Specifically, we aimed to compare the weekly acute load, monotony, and training strain of accelerometry-based measures across a professional soccer season (pre-season, first and second halves of the season) according to players' positions. Nineteen professional players were monitored daily for 45 weeks using an 18-Hz global positioning system to obtain measures of high metabolic load distance (HMLD), impacts, and high intensity accelerations and decelerations. Workload indices of acute load, training monotony, and training strain were calculated weekly for each of the measures. The HMLD had greater training strain values in the pre-season than in the first ($p \leq 0.001$; $d = 0.793$) and second halves of the season ($p \leq 0.001$; $d = 0.858$). Comparisons between playing positions showed that midfielders had the highest weekly acute load of HMLD (6901 arbitrary units [AU]), while central defenders had the lowest (4986 AU). The pre-season period was associated with the highest acute and strain load of HMLD and number of impacts, with a progressive decrease seen during the season. In conclusion, coaches should consider paying greater attention to variations in HMLD and impacts between periods of the season and between players to individualize training accordingly.

INTRODUCTION

The individualization of the training process requires the systematic monitoring of training's impact on players, namely by controlling training load and well-being measures of readiness [1]. Among these aspects, training load quantification has become an important area of study within sports sciences departments [2]. Load monitoring allows the collection of either objective or subjective measures that provide information that is useful to understand the dynamics of load and promoting adjustments in the training process [3]. Two main dimensions are included in load monitoring [4]: (i) external load, which is associated with the physical demands or mechanical work promoted by the exercise, and (ii) internal load, which is associated with psychobiological responses to external load. Usually, in team

sports, external load is quantified by positioning-derived data (e.g., data obtained from global positioning systems [GPSs] or multi-camera tracking systems) or accelerometry-derived data (e.g., data obtained from inertial sensor units [IMUs]; or accelerometers) [5]. However, GPS units are commonly equipped with accelerometers or IMUs, which makes it possible to obtain position-derived data (e.g., distances covered at different speeds, changes in velocity) and accelerometry-derived data (e.g., accelerations/decelerations, player load, impacts, stride) at the same time [6, 7]. The integration of accelerometers allows researchers to continuously record signals at a high measuring frequency (commonly, 100 Hz), thus making it possible to acquire summative measures such as player load, dynamic

stress load, or metabolic power [8, 9]. However, there are some issues related to the use and interpretation of measures derived from GPSs [6, 10]. Some measures (e.g., distance) can be highly dependent on tactical contexts and players' fitness status, among other factors [6]. On the other hand, accelerometry-derived measures seem to be more stable even considering variations across sessions and matches, and so they are better for monitoring specific elements, such as fitness or fatigue, over time [6]. Training load monitoring might recognize some training principles such as individualization, progression, overload, or variability of the stimulus [11]. Additionally, within- and between-week variations in external load can be monitored to reduce the chances of overtraining and undertraining [12, 13].

Some workload measures have been used to monitor training load. Among others, the acute-to-chronic workload ratio (acute load divided by chronic load) [14] could control weekly progression and overload in players. However, other important aspects related to the capacity to identify exposures to high doses and minimal within-week variability can be controlled using training monotony and training strain [15]. These two measures were introduced to monitor exposure to bad overreaching or overtraining using the session rate of perceived exertion (sRPE), which is RPE multiplied by the duration of a training session, in minutes [15]. Training monotony is the daily mean load divided by the week standard deviation load, while training strain is the product of weekly training load and monotony [15]. These concepts have been tested to identify possible exposures to injury risk or illness, or associations with decrements in performance [16–19]. Despite attempts to use sRPE to control overload, some evidence suggests that training strain and monotony may better reflect players' exposure to injury risk [17, 20]. However, the relationships of training monotony and training strain with exposure to injury or illness risk are likely complex [21]. In this sense,

modulators such as players' fitness (i.e., professional vs. amateur) and the season period (i.e., pre-season vs. in-season) must be analysed. Although these specific definitions of monotony and strain are restrictive and likely do not reflect the complexity involved in defining actual monotony and strain, we use these well-established concepts in the present work. Despite the regular practice of controlling training monotony and strain using sRPE, these indices have not been used often to assess external load. One of the few studies that has done this [22] was employed using a new measure that integrates internal and external load measures. However, mechanical work resulting from training sessions should also be considered as a factor that could induce adaptations or fatigue. Furthermore, controlling within-week variations and changes across the weeks could provide sports scientists and coaches with important information about possible differences at different moments of the season or even between playing positions. Based on previous studies [23], meaningful variations in weekly loads can be found between different moments within a season. Moreover, considering the great number of drills based on the game, it is also expected that meaningful variations in external load could occur between playing positions. Therefore, the aim of this study was to describe and compare the weekly acute load, monotony, and training strain of accelerometry-based measures across different moments of a professional soccer season (pre-season, first and second halves of the season) according to players' positions. It is hypothesized that greater workload indices occur during the pre-season and that meaningful variations occur in the workload indices between playing positions.

MATERIALS AND METHODS

Experimental approach and procedures

Using a descriptive research design, a squad of 19 professional male soccer players was monitored daily throughout a full season. The
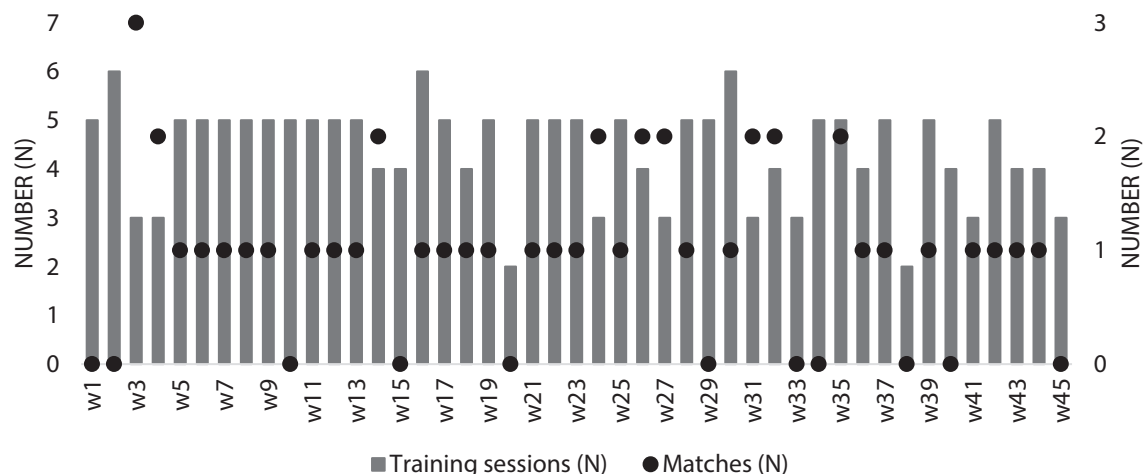

FIG. 1. Weekly distribution of training sessions and matches across the season. w: week

external load monitored by an 18-Hz GPS unit (including accelerometer) was controlled in all training sessions (n = 197) and matches (n = 44; including national league, national cup, and European league matches). Data covering 45 weeks were analysed. The study period began at the beginning of the pre-season (July 3, 2018) and lasted until the end of the season (May 9, 2019). The season was organized into three periods: (i) pre-season (PS: week 1 to week 6, no official matches); (ii) first half of the season (1stHS: week 6 to week 33, covering the period from the first to the last match of the first round of the national league); and (iii) the second half of the season (2ndHS: week 34 to week 45, covering the period from the first to the last match of the second round of the national league). A graphical depiction of the weekly distribution of training sessions and matches across the season is presented in Figure 1.

The following accelerometry-derived measures were monitored daily for each player: (i) high metabolic power distance; (ii) number of impacts; (iii) high intensity accelerations and decelerations. These measures were then calculated weekly to obtain values for acute load, training monotony, and training strain for each player.

Participants
Nineteen elite professional male players (age: 26.5 ± 4.3 years; body mass: 75.6 ± 9.6 kg; height: 180.2 ± 7.3 cm; experience as professionals: 7.5 ± 4.3 years) from a European First League team participated in this study. Players were categorized by playing position as external defenders (ED, n = 3), central defenders (CD, n = 4), midfielders (MF, n = 6), wingers (W, n = 4), and strikers (ST, n = 2). Inclusion criteria were (i) the player must belong to the team from day 1 to the last day of the season; (ii) players could not stop training for more than two consecutive weeks (due to injuries or illness); (iii) players participated in more than 80% of the training sessions. From a total of 31 players, nine were excluded based on these criteria. The remaining three were excluded for acting as goalkeepers. The players were familiarized with the study design and protocol, as well as with the daily procedures before beginning. After their agreement, they signed a free informed consent form. The study followed the ethical guidelines of the Declaration of Helsinki. The study was approved by the scientific council of Escola Superior de Desporto e Lazer (Portugal).

External load monitoring
External load was quantified using an 18-Hz GPS with a 100-Hz gyroscope, 100-Hz tri-axial accelerometer, and 10-Hz magnetometer (STATSports, Apex, Northern Ireland). This GPS unit was previously tested for validity and reliability, with good levels of accuracy (< 2.3% coefficient of variation) [24] and excellent levels of inter-unit reliability for peak running velocity observed [25]. The number of satellites during data collection ranged between 17 and 21. Each player used the same unit during the period of data collection to reduce possible inter-unit variability. Each player used a vest in which the GPS unit was positioned between their scapulae. The data obtained from the GPS were downloaded and analysed in specific software (STATSports Apex software, version 5.0).

The following measures were collected daily from each player: (i) high metabolic load distance (HMLD: corresponding to the distance covered at a speed of > 5.5 m/s^{-1} while accelerating/decelerating at ≥ 2 m/s^{-2}); (ii) impacts (Imp: the number of impacts, which are considered instantaneous moments throughout a training session measured in G-forces and expressed as quantity); (iii) high intensity accelerations and decelerations (HA and HD: number of accelerations and decelerations at ≥ 3 m/s^{-2} maintained for ≥0.5 seconds). Weekly acute load (within-week training sessions and matches summed load), training monotony (mean of training load during the seven days of the week divided by its standard deviation) and training strain (sum of training load for all training sessions and matches during a week multiplied by training monotony) were calculated for each variable and for each player. Considering the acute load, training monotony and training strain (weekly representation), the GPS measures were calculated as follows: (i) weekly HMLD (wHMLD); (ii) mHMLD (monotony HMLD); (iii) sHMLD (strain HMLD); (iv) wImp (weekly Imp); (v) mImp (monotony Imp); (vi) sImp (strain Imp); (vii) wHA (weekly HA); (viii) mHA (monotony HA); (ix) sHA (strain HA); (x) wHD (weekly HD); (xi) mHD (monotony HD); and (xii) sHD (strain HD).

Statistical procedures
Means (with standard deviation) are indicated. Normality (N > 30, thus assuming the central limit theorem) and homogeneity (Levene; p > 0.05) were preliminarily tested and confirmed. The weekly load (acute; monotony; strain) was compared between periods of the season (PS; 1stHS; 2ndHS) using a repeated measures ANOVA followed by Tukey's HSD post hoc test for pairwise comparisons. To compare playing positions (ED; CD; MF; W; ST), a one-way ANOVA was used, followed by the Tukey HSD post hoc test for pairwise comparisons. Both tests were executed in SPSS software (version 25.0, IBM, Chicago, USA), with p < 0.05. The magnitudes of differences in pairwise comparisons were tested using the standardized effect size of Cohen (d) for a 95% confidence interval (95%CI). The inference of magnitudes was made using the following thresholds [26]: [0.0;0.2], trivial; [0.2;0.6], small; [0.6;1.2], moderate; [1.2; 2.0], large; > 2.0, very large.

RESULTS ▮▮▮▮▮▮▮▮▮
The weekly changes in acute load and training monotony over the season for HMLD can be found in Figure 2 (a). The highest weekly acute load (12,277 m) was reached in week 1, and the lowest (2942 m) was recorded in week 43. The highest weekly acute load increase was 99% (from week 29 to week 30), and the largest decrease was -63% (week 19 to 20). Training monotony was the highest in week 45 (5.7 arbitrary units [AU]) and the lowest in week 24 (0.7 AU). The greatest between-week increase (438%) in training monotony occurred between weeks 44 and 45, while the largest
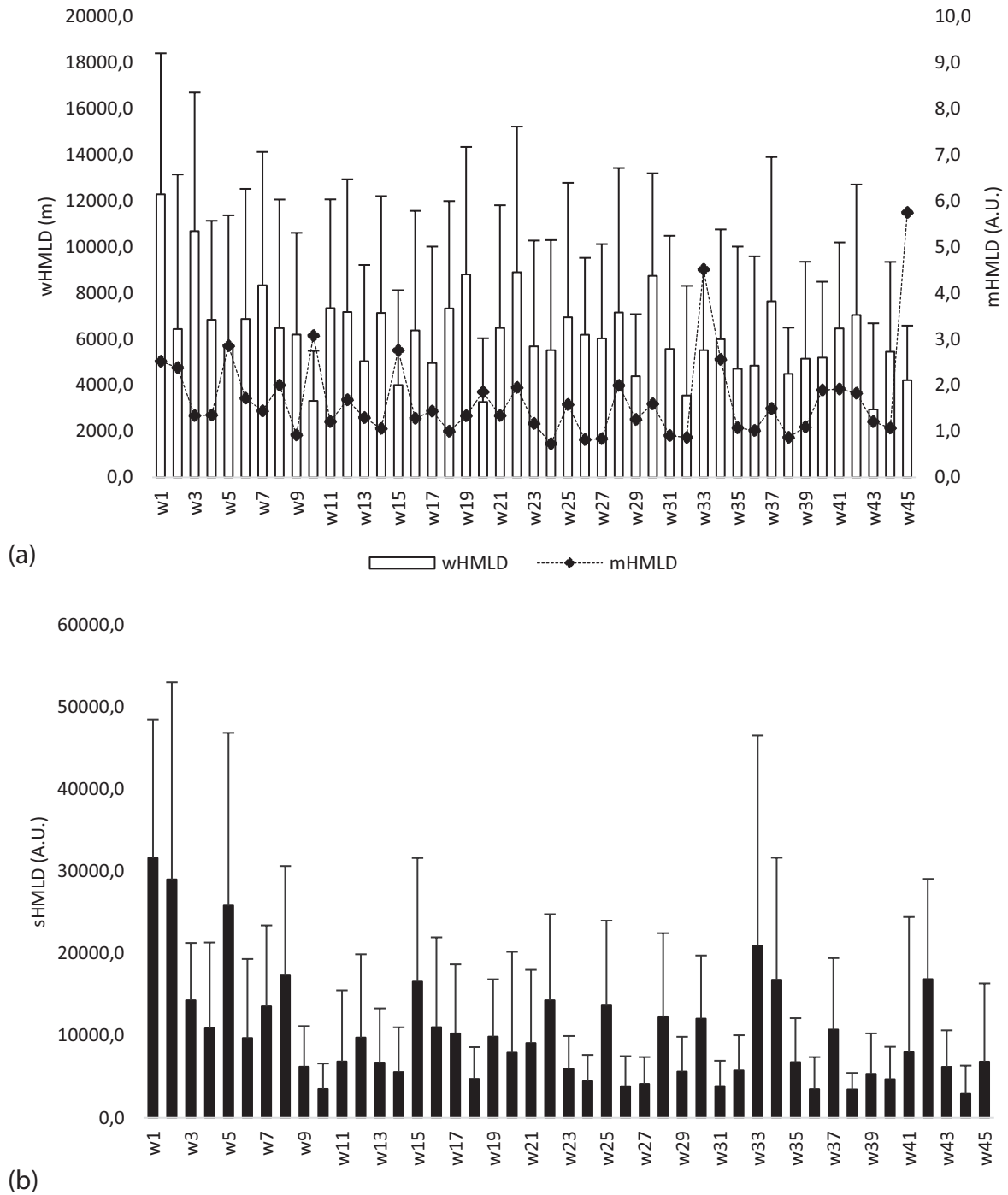
(a)

(b)

FIG. 2. Weekly distribution across the season for (a) weekly high metabolic load distances (wHMLD), monotony HMLD (mHMLD), and (b) strain HMLD (sHMLD).

decrease (-61%) occurred between weeks 10 and 11. Training strain was highest in week 1 (31638 AU) and lowest in week 44 (2912 AU), while the largest increase (265%) was found from week 32 to week 33, and the largest decrease (-63%) was found from week 42 to week 43 (Figure 2 (b)).

Figure 3 (a) shows the weekly changes in acute load and training monotony for high intensity accelerations. The highest weekly

acute load reached 1833 n in week 16, and the lowest load was found in week 10 (384 n). The greatest increase (179%) occurred between week 29 and week 30, while the largest decrease (-72%) occurred between week 37 and week 38. Training monotony was highest in week 38 (5.2 AU) and lowest in week 10 (0.7 AU). The largest increase, reaching 311%, was found from week 32 to 33, while the largest decrease (-77%) was found from
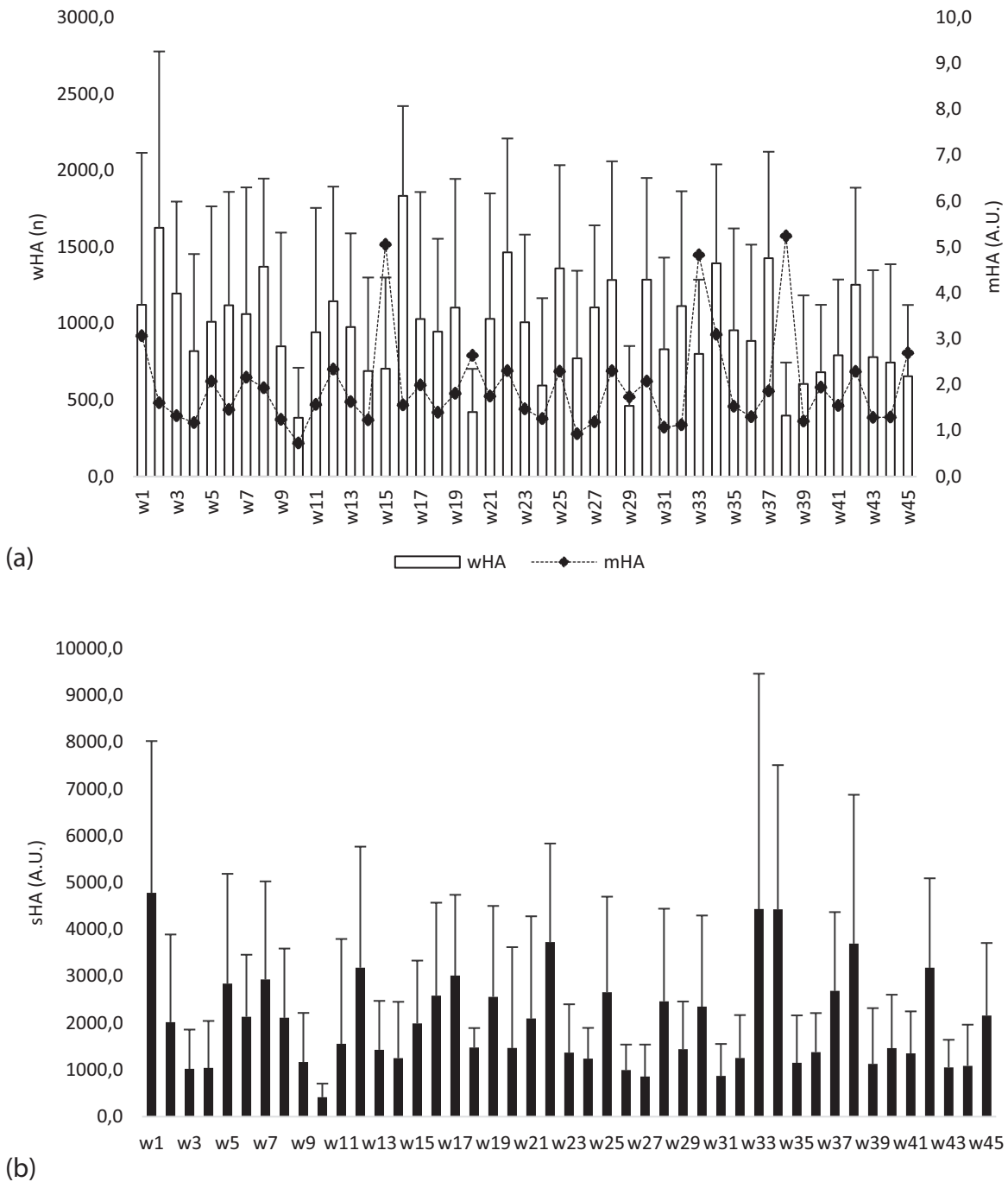
(a)

(b)

FIG. 3. Descriptive statistics of (a) acute load and training monotony and (b) training strain for high intensity accelerations.

week 38 to week 39. As seen in Figure 3 (b), training strain was highest in week 1 (4781 AU) and lowest in week 10 (415 AU). The largest increase (254%) was found from week 32 to week 33, while the largest decrease (-74%) was found from week 34 to week 35.

Figure 4 (a) shows the weekly changes of acute load and training monotony for high intensity decelerations. The highest weekly acute load (1762 n) was reached in week 2, while the lowest (418 n) was reached in week 20. The largest increase (158%) was observed from week 15 to week 16, and the largest decrease (-61%) occurred from week 19 to week 20. Training monotony was highest in week 33 (5.2 AU) and lowest in week 10 (0.7 AU). The largest increase in training monotony (382%) occurred from week 32 to week 33, while the largest decrease (-76%) was observed from week 38 to week
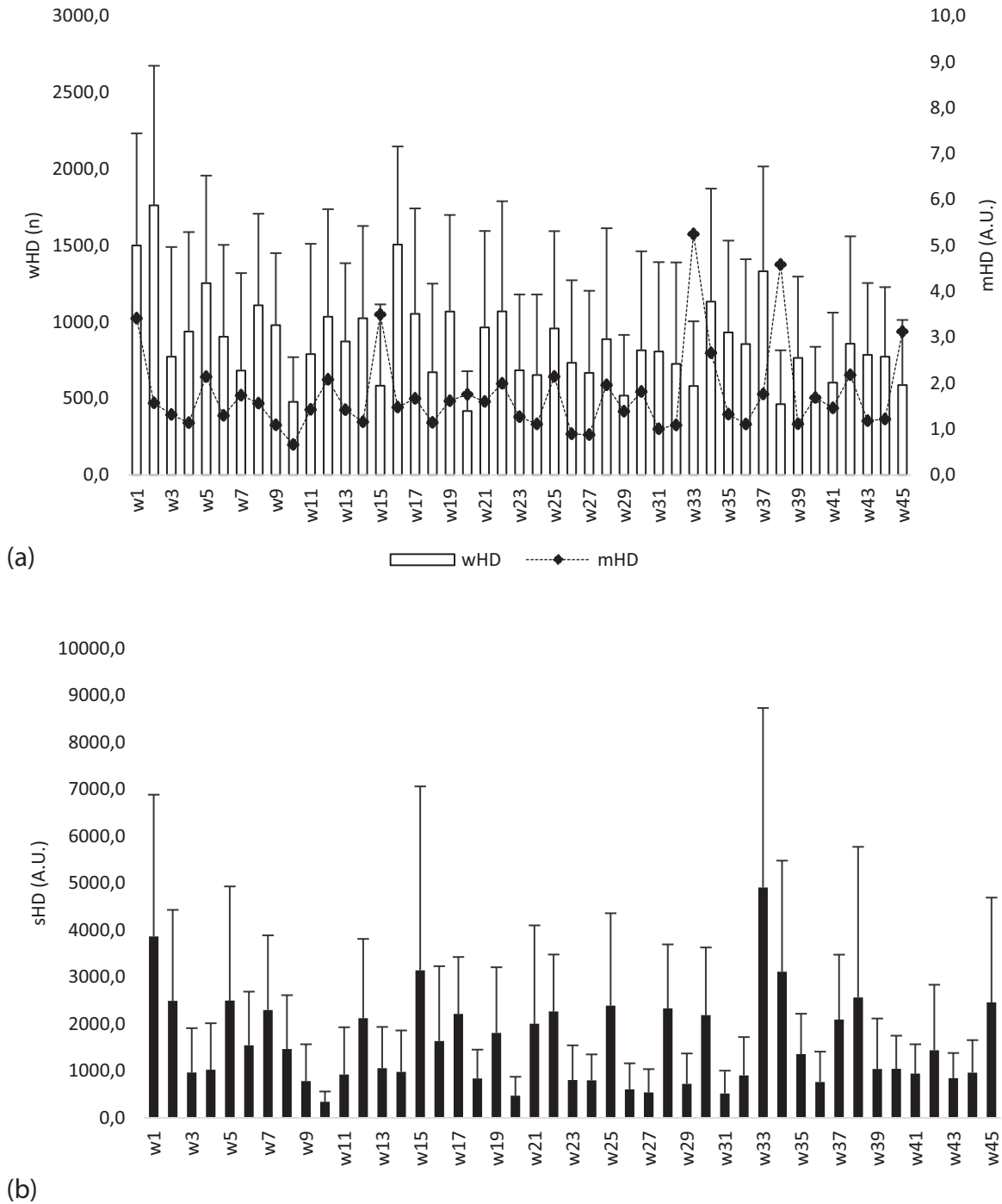
FIG. 4. Descriptive statistics of (a) acute load and training monotony and (b) training strain for high intensity decelerations.

39. Figure 4 (b) indicates that training strain was highest in week 33 (4909 AU) and lowest in week 10 (341 AU). The largest increase in training strain (443%) was reached from week 32 to week 33, while the largest decrease (-56%) was found from week 34 to week 35.

Figure 5 (a) shows the weekly changes in acute load and training monotony for impacts. The highest weekly acute load (3333 n)

was reached in week 2, and the lowest acute load was found in week 31 (336 n). The largest increase in acute load (194%) occurred from week 15 to week 17, and the largest decrease (-78%) occurred from week 30 to week 31. Training monotony was highest in week 1 (3.8 AU) and lowest in weeks 9 and 24 (0.6 AU). The largest increase in training monotony (404%) was found from week 9 to week 10. As seen in Figure 5 (b), training strain was
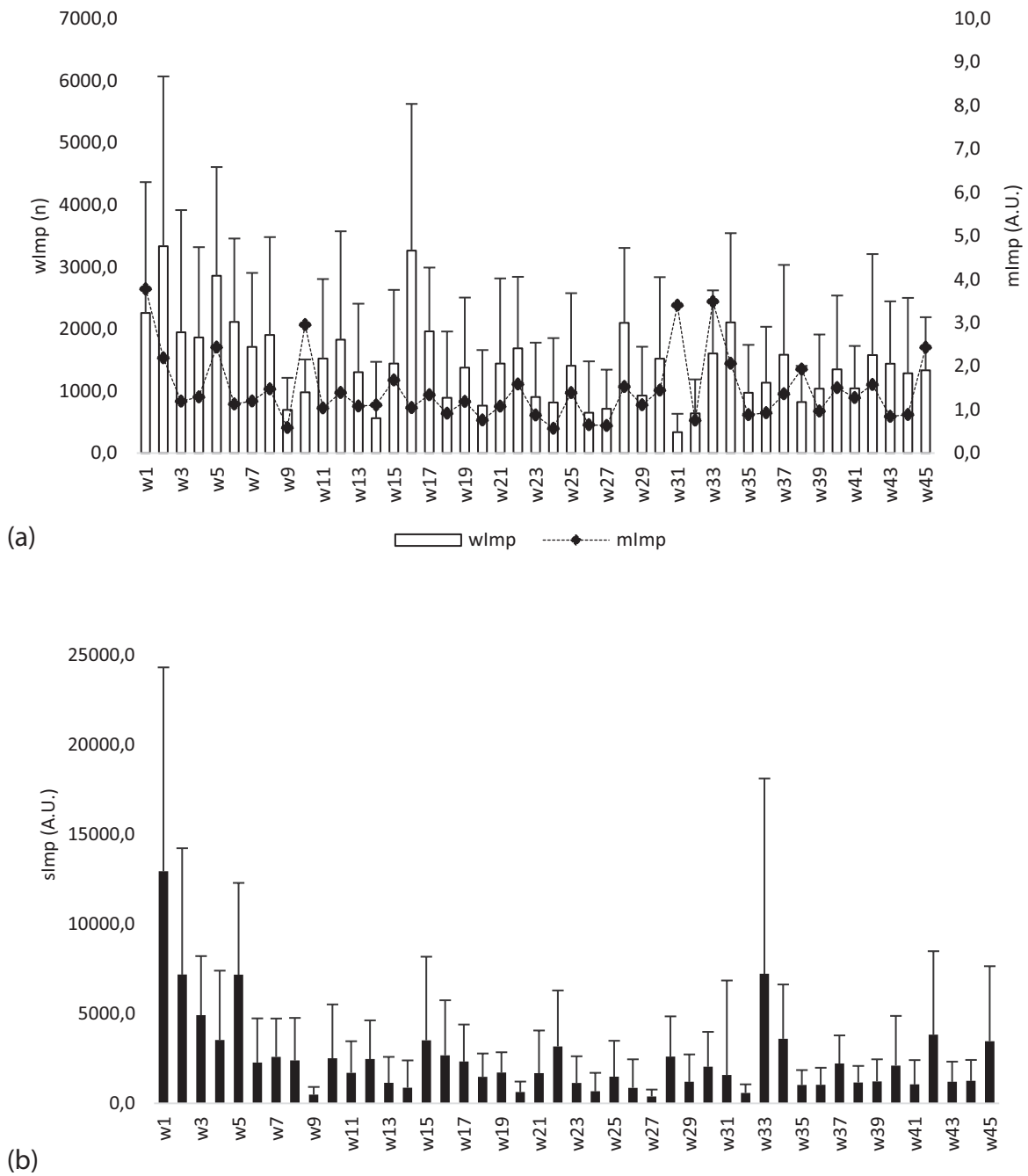
(a)

(b)

FIG. 5. Descriptive statistics of (a) acute load and training monotony and (b) training strain for impacts.

highest in week 1 (12,949 AU) and lowest in week 27 (388 AU). The largest increase in training strain (495%) occurred from week 32 to week 33, while the largest decrease (-54%) was found from week 5 to week 6.

Table 1 presents the differences between the PS, 1stHS, and 2ndHS for AL, TM, and TS for HMLD, Imp, HA, and HD. To simplify the description, only moderate to large ESs will be described

here. In relation to wHMLD, meaningfully greater TS values were observed in the PS than in the 1stHS (88%) and 2ndHS (46%). Also, wImp was meaningfully greater in the PS than in the 1stHS (74%) and 2ndHS (66%). Similarly, mImp was meaningfully greater in PS than in the 1stHS (50%) and 2ndHS (50%). Moreover, sImp was meaningfully greater in the PS than in the 1stHS (167%) and 2nHS (145%).

TABLE 1. Descriptive statistics (mean ± SD) of acute load, training monotony, and training strain for external load measures in the pre-season, first half of the season, and second half of the season.

	PS (mean ± SD)	1stHS (mean ± SD)	2ndHS (mean ± SD)	p	ES
wHMLD (m)	7875.0 ± 6007.1	6317.5 ± 4966.9	5384.7 ± 4508.8	PS vs. 1stHS: 0.027* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.05	PS vs. 1stHS: 0.304 *small* PS vs. 2ndHS: 0.504 *small* 1stHF vs. 2ndHS: 0.193 *trivial*
mHMLD (AU)	2.0 ± 1.2	1.5 ± 1.1	1.5 ± 1.0	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.990	PS vs. 1stHS: 0.449 *small* PS vs. 2ndHS: 0.474 *small* 1stHF vs. 2ndHS: 0.000 *trivial*
sHMLD (AU)	16360.0 ± 14361.3	8717.9 ± 8719.5	7520.7 ± 8590.3	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.265	PS vs. 1stHS: 0.793 *moderate* PS vs. 2ndHS: 0.858 *moderate* 1stHF vs. 2ndHS: 0.138 *trivial*
wImp (n)	2190.7 ± 1695.7	1258.1 ± 1175.3	1314.4 ± 1109.9	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.835	PS vs. 1stHS: 0.742 *moderate* PS vs. 2ndHS: 0.683 *moderate* 1stHF vs. 2ndHS: 0.049 *trivial*
mImp (AU)	1.8 ± 1.0	1.2 ± 0.9	1.2 ± 0.8	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.740	PS vs. 1stHS: 0.656 *moderate* PS vs. 2ndHS: 0.701 *moderate* 1stHF vs. 2ndHS: 0.000 *trivial*
sImp (AU)	4450.3 ± 4482.7	1666.5 ± 2125.4	1815.4 ± 2062.7	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.733	PS vs. 1stHS: 1.092 *moderate* PS vs. 2ndHS: 0.930 *moderate* 1stHF vs. 2ndHS: -0.070 *trivial*
wHA (n)	1137.2 ± 828.5	985.3 ± 707.2	908.4 ± 645.1	PS vs. 1stHS: 0.181 PS vs. 2ndHS: 0.036* 1stHF vs. 2ndHS: 0.367	PS vs. 1stHS: 0.210 *small* PS vs. 2ndHS: 0.329 *small* 1stHF vs. 2ndHS: 0.112 *small*
mHA (AU)	1.7 ± 0.8	1.7 ± 0.9	1.8 ± 1.0	PS vs. 1stHS: >0.999 PS vs. 2ndHS: 0.617 1stHF vs. 2ndHS: 0.294	PS vs. 1stHS: 0.000 *trivial* PS vs. 2ndHS: -0.105 *trivial* 1stHF vs. 2ndHS: -0.107 *trivial*
sHA (AU)	2222.8 ± 2162.9	1974.4 ± 1794.6	1808.3 ± 1514.2	PS vs. 1stHS: 0.489 PS vs. 2ndHS: 0.183 1stHF vs. 2ndHS: 0.487	PS vs. 1stHS: 0.134 *trivial* PS vs. 2ndHS: 0.243 *small* 1stHF vs. 2ndHS: 0.097 *trivial*
wHD (AU)	1156.5 ± 773.5	824.1 ± 610.1	817.1 ± 588.3	PS vs. 1stHS: ≤ 0.001* PS vs. 2ndHS: ≤ 0.001* 1stHF vs. 2ndHS: 0.989	PS vs. 1stHS: 0.523 *small* PS vs. 2ndHS: 0.529 *small* 1stHF vs. 2ndHS: 0.012 *trivial*
mHD (AU)	1.7 ± 0.8	1.6 ± 1.1	1.7 ± 0.9	PS vs. 1stHS: 0.575 PS vs. 2ndHS: >0.999 1stHF vs. 2ndHS: 0.279	PS vs. 1stHS: 0.094 *trivial* PS vs. 2ndHS: 0.000 *trivial* 1stHF vs. 2ndHS: -0.096 *trivial*
sHD (AU)	1810.4 ± 1760.4	1465.2 ± 1442.5	1455.5 ± 1449.2	PS vs. 1stHS: 0.149 PS vs. 2ndHS: 0.175 1stHF vs. 2ndHS: 0.996	PS vs. 1stHS: 0.232 *small* PS vs. 2ndHS: 0.232 *small* 1stHF vs. 2ndHS: 0.007 *trivial*

HA: high intensity accelerations; HD: high intensity decelerations; HMLD: high metabolic load distance; wHMLD: weekly HMLD; mHMLD: monotony HMLD; sHMLD: strain HMLD; wImp: weekly impacts; mImp: monotony impacts; sImp: strain impacts; wHA: weekly HA; mHA: monotony HA; sHA: strain HA ; wHD: weekly HD; mHD: monotony HD; sHD: strain HD; PS: pre-season period; 1stHS: first half of the season; 2ndHS: second half of the season; AU: arbitrary units; ES: effect size.

Tables 2, 3, 4, and 5 present the differences between playing positions, AL, TM, and TS for HMLD, Imp, HA, and HD. To simplify the description, only small ESs will be described here. Significantly greater wHMLD were found for ED, MF, W, ST than for CD (24, 38, 31%, and 17%, respectively). Also, MF and W had significantly greater wHMLD values than ST (18% and 12%, respectively). No significant differences were found between positions for mHMLD, while for sHMLD greater values were found for W than for CD and ST (30% and 26%, respectively).

TABLE 2. Descriptive statistics (mean ± SD) of acute load, training monotony, and training strain for HMLD between playing positions.

	ED (mean ± SD)	CD (mean ± SD)	MF (mean ± SD)	W (mean ± SD)	ST (mean ± SD)	p	ES
wHMLD (m)	6194.8 ± 5229.2	4985.5 ± 3915.4	6900.5 ± 5414.9	6514.2 ± 5070.5	5840.9 ± 4521.3	ED vs. CD: 0.204 ED vs. MF: 0.632 ED vs. W: 0.978 ED vs. ST: 0.985 CD vs. MF: 0.002* CD vs. W: 0.056 CD vs. ST: 0.725 MF vs. W: 0.942 MF vs. ST: 0.462 W vs. ST: 0.858	ED vs. CD: 0.260 *small* ED vs. MF: -0.132 *trivial* ED vs. W: -0.062 *trivial* ED vs. ST: 0.070 *trivial* CD vs. MF: -0.392 *small* CD vs. W: -0.336 *small* CD vs. ST: -0.207 *small* MF vs. W: 0.073 *trivial* MF vs. ST: 0.204 *small* W vs. ST: 0.138 *small*
mHMLD (AU)	1.5 ± 0.9	1.6 ± 1.3	1.5 ±	1.5 ± 1.1	1.4 ± 0.6	ED vs. CD: 0.743 ED vs. MF: >0.999 ED vs. W: 0.996 ED vs. ST: 0.973 CD vs. MF: 0.631 CD vs. W: 0.913 CD vs. ST: 0.491 MF vs. W: 0.989 MF vs. ST: 0.977 W vs. ST: 0.889	ED vs. CD: 0.090 *trivial* ED vs. MF: 0.000 *trivial* ED vs. W: 0.000 *trivial* ED vs. ST: 0.123 *trivial* CD vs. MF: 0.081 *trivial* CD vs. W: 0.083 *trivial* CD vs. ST: 0.182 *trivial* MF vs. W: 0.000 *trivial* MF vs. ST: 0.093 *trivial* W vs. ST: 0.104 *trivial*
sHMLD (AU)	9355.9 ± 10346.4	7910.8 ± 7884.9	9127.3 ± 10137.4	10313.6 ± 10433.2	8202.4 ± 7763.4	ED vs. CD: 0.698 ED vs. MF: 0.999 ED vs. W: 0.907 ED vs. ST: 0.910 CD vs. MF: 0.763 CD vs. W: 0.202 CD vs. ST: >0.999 MF vs. W: 0.763 MF vs. ST: 0.948 W vs. ST: 0.508	ED vs. CD: 0.156 *trivial* ED vs. MF: 0.022 *trivial* ED vs. W: -0.092 *trivial* ED vs. ST: 0.121 *trivial* CD vs. MF: -0.130 *trivial* CD vs. W: -0.258 *small* CD vs. ST: -0.037 *trivial* MF vs. W: -0.116 *trivial* MF vs. ST: 0.097 *trivial* W vs. ST: 0.220 *small*

wHMLD: weekly high metabolic load distance; mHMLD: monotony high metabolic load distance; sHMLD: strain high metabolic load distance; ED: external defender; CD: central defender; MF: midfielder; W: winger; ST: striker; AU: arbitrary units; ES: effect size

Greater wImp was found for ED than for CD, W, and ST (31%, 43%, and 50%, respectively). The mImp was greater for ED and CD than for ST (18% in both cases). Furthermore, the sImp was greater for ED than for CD, W, and ST (44%, 95%, and 91%, respectively).

TABLE 3. Descriptive statistics (mean ± SD) of acute load, training monotony, and training strain for the impacts between playing positions.

	ED (mean ± SD)	CD (mean ± SD)	MF (mean ± SD)	W (mean ± SD)	ST (mean ± SD)	p	ES
wImp (n)	1569.4 ± 1490.0	1199.6 ± 963.9	1617.6 ± 1325.4	1099.1 ± 1086.2	1044.4 ± 1000.5	ED vs. CD: 0.064 ED vs. MF: 0.995 ED vs. W: 0.006* ED vs. ST: 0.016* CD vs. MF: 0.011* CD vs. W: 0.952 CD vs. ST: 0.892 MF vs. W: ≤0.001* MF vs. ST: 0.003* W vs. ST: 0.998	ED vs. CD: 0.292 *small* ED vs. MF: -0.035 *trivial* ED vs. W: 0.361 *small* ED vs. ST: 0.390 *small* CD vs. MF: -0.349 *small* CD vs. W: 0.098 *trivial* CD vs. ST: 0.159 *trivial* MF vs. W: 0.420 *small* MF vs. ST: 0.458 *small* W vs. ST: 0.052 *trivial*
mImp(AU)	1.3 ± 0.9	1.3 ± 0.8	1.3 ± 1.1	1.2 ± 1.0	1.1 ± 0.7	ED vs. CD: 0.990 ED vs. MF: >0.999 ED vs. W: 0.537 ED vs. ST: 0.642 CD vs. MF: 0.970 CD vs. W: 0.843 CD vs. ST: 0.872 MF vs. W: 0.373 MF vs. ST: 0.526 W vs. ST: >0.999	ED vs. CD: ≤0.001 *trivial* ED vs. MF: ≤ 0.001 *trivial* ED vs. W: 0.105 *trivial* ED vs. ST: 0.239 *small* CD vs. MF: ≤0.001 *trivial* CD vs. W: 0.115 *trivial* CD vs. ST: 0.286 *small* MF vs. W: 0.094 *trivial* MF vs. ST: 0.198 *trivial* W vs. ST: 0.110 *trivial*
sImp (AU)	2694.7 ± 3514.1	1874.1 ± 2350.6	2116.7 ± 2399.2	1382.5 ± 1893.9	1411.1 ± 1565.2	ED vs. CD: 0.040* ED vs. MF: 0.178 ED vs. W: ≤ 0.001* ED vs. ST: 0.002* CD vs. MF: 0.897 CD vs. W: 0.440 CD vs. ST: 0.685 MF vs. W: 0.040* MF vs. ST: 0.204 W vs. ST: >0.999	ED vs. CD: 0.272 *small* ED vs. MF: 0.199 *trivial* ED vs. W: 0.466 *small* ED vs. ST: 0.427 *small* CD vs. MF: -0.102 *trivial* CD vs. W: 0.232 *small* CD vs. ST: 0.220 *small* MF vs. W: 0.333 *small* MF vs. ST: 0.319 *small* W vs. ST: -0.016 *trivial*

wImp: weekly impacts; mImp: monotony impacts; sImp: strain impacts; ED: external defender; CD: central defender; MF: midfielder; W: winger; ST: striker; AU: arbitrary units; ES: effect size

External load between positions and periods of the season

No significant differences were found between positions for the different workload indices calculated for HA.

TABLE 4. Descriptive statistics (mean ± SD) of acute load, training monotony, and training strain for the HA between playing positions.

	ED (mean ± SD)	CD (mean ± SD)	MF (mean ± SD)	W (mean ± SD)	ST (mean ± SD)	p	ES
wHA (n)	1064.8 ± 742.2	1035.2 ± 699.0	911.8 ± 718.7	995.4 ± 697.0	941.8 ± 600.9	ED vs. CD: 0.996 ED vs. MF: 0.210 ED vs. W: 0.632 ED vs. ST: 0.702 CD vs. MF: 0.456 CD vs. W: 0.859 CD vs. ST: 0.874 MF vs. W: 0.975 MF vs. ST: 0.997 W vs. ST: <0.999	ED vs. CD: 0.041 *trivial* ED vs. MF: 0.210 *small* ED vs. W: 0.152 *trivial* ED vs. ST: 0.176 *trivial* CD vs. MF: 0.174 *trivial* CD vs. W: 0.114 *trivial* CD vs. ST: 0.140 *trivial* MF vs. W: -0.061 *trivial* MF vs. ST: -0.043 *trivial* W vs. ST: 0.020 *trivial*
mHA (AU)	1.8 ± 1.0	1.8 ± 0.9	1.7 ± 0.9	1.8 ± 1.0	1.8 ± ±	ED vs. CD: 0.996 ED vs. MF: 0.860 ED vs. W: 0.969 ED vs. ST: 0.989 CD vs. MF: 0.653 CD vs. W: 0.999 CD vs. ST: <0.999 MF vs. W: 0.451 MF vs. ST: 0.698 W vs. ST: <0.999	ED vs. CD: ≤0.001 *trivial* ED vs. MF: 0.106 *trivial* ED vs. W: ≤0.001 *trivial* ED vs. ST: ≤0.001 *trivial* CD vs. MF: 0.111 *trivial* CD vs. W: ≤0.001 *trivial* CD vs. ST: ≤0.001 *trivial* MF vs. W: -0.106 *trivial* MF vs. ST: -0.114 *trivial* W vs. ST: ≤0.001 *trivial*
sHA (AU)	1977.4 ± 1782.3	2075.7 ± 1738.1	1807.2 ± 1666.3	2148.1 ± 1934.0	1717.2 ± 1669.3	ED vs. CD: 0.989 ED vs. MF: 0.913 ED vs. W: 0.822 ED vs. ST: 0.989 CD vs. MF: 0.610 CD vs. W: 0.997 CD vs. ST: 0.595 MF vs. W: 0.339 MF vs. ST: 0.995 W vs. ST: 0.392	ED vs. CD: -0.056 *trivial* ED vs. MF: 0.099 *trivial* ED vs. W: -0.092 *trivial* ED vs. ST: 0.149 *trivial* CD vs. MF: 0.159 *trivial* CD vs. W: -0.039 *trivial* CD vs. ST: 0.209 *small* MF vs. W: -0.192 *trivial* MF vs. ST: 0.054 *trivial* W vs. ST: 0.233 *small*

wHA: weekly high intensity accelerations; mHA: monotony high intensity accelerations; sHA: strain high intensity accelerations; ED: external defender; CD: central defender; MF: midfielder; W: winger; ST: striker; AU: arbitrary units; ES: effect size

TABLE 5. Descriptive statistics (mean ± SD) of acute load, training monotony, and training strain for the HD between playing positions.

	ED (mean ± SD)	CD (mean ± SD)	MF (mean ± SD)	W (mean ± SD)	ST (mean ± SD)	p	ES
wHD (n)	956.8 ± 637.3	786.0 ± 595.0	820.0 ± 650.8	917.8 ± 650.9	755.5 ± 535.8	ED vs. CD: 0.118 ED vs. MF: 0.206 ED vs. W:0.981 ED vs. ST: 0.127 CD vs. MF: 0.986 CD vs. W: 0.351 CD vs. ST: 0.997 MF vs. W: 0.550 MF vs. ST: 0.931 W vs. ST: 0.319	ED vs. CD: 0.277 *small* ED vs. MF: 0.212 *small* ED vs. W: 0.060 *trivial* ED vs. ST: 0.333 *small* CD vs. MF: -0.054 *trivial* CD vs. W: -0.211 *small* CD vs. ST: 0.053 *trivial* MF vs. W: -0.150 *trivial* MF vs. ST: 0.104 *trivial* W vs. ST: 0.264 *small*
mHD (AU)	1.6 ± 1.0	1.6 ± 0.8	1.6 ± 1.3	1.7 ± 1.0	1.7 ± 0.7	ED vs. CD: <0.999 ED vs. MF: 0.999 ED vs. W: 0.997 ED vs. ST: 0.993 CD vs. MF: 0.996 CD vs. W: 0.999 CD vs. ST: 0.998 MF vs. W: 0.968 MF vs. ST: 0.965 W vs. ST: <0.999	ED vs. CD: ≤0.001 *trivial* ED vs. MF: ≤0.001 *trivial* ED vs. W: -0.100 *trivial* ED vs. ST: -0.110 *trivial* CD vs. MF: ≤0.001 *trivial* CD vs. W: ≤0.001 *trivial* CD vs. ST: -0.131 *trivial* MF vs. W: -0.084 *trivial* MF vs. ST: -0.085 *trivial* W vs. ST: -0.110 *trivial*
sHD (AU)	1510.0 ± 1517.5	1326.6 ± 1289.6	1534.0 ± 1496.3	1673.1 ± 1670.1	1309.2 ± 1233.1	ED vs. CD: 0.821 ED vs. MF: 1.000 ED vs. W: 0.865 ED vs. ST: 0.862 CD vs. MF: 0.687 CD vs. W: 0.257 CD vs. ST: <0.999 MF vs. W: 0.895 MF vs. ST: 0.772 W vs. ST: 0.383	ED vs. CD: 0.130 *trivial* ED vs. MF: -0.016 *trivial* ED vs. W: -0.102 *trivial* ED vs. ST: 0.141 *trivial* CD vs. MF: -0.146 *trivial* CD vs. W: -0.231 *small* CD vs. ST: 0.014 *trivial* MF vs. W: -0.089 *trivial* MF vs. ST: 0.157 *trivial* W vs. ST: 0.237 *small*

wHD: weekly high intensity decelerations; mHD: monotony high intensity decelerations; sHD: strain high intensity decelerations; ED: external defender; CD: central defender; MF: midfielder; W: winger; ST: striker; AU: arbitrary units; ES: effect size

DISCUSSION

The aim of this study was to describe and compare the weekly acute load, monotony, and training strain of accelerometry-based measures across a professional soccer season (pre-season, first and second halves of the season) according to players' positions. The main results revealed that among professional male soccer players, greater training monotony and strain (including impacts and HMLD) occurred in the pre-season than during the season. Moreover, such results were modulated by the player's position.

Weekly high metabolic load distances varied between 5385 m and 7875 m. Similarly, in a study on 28 elite soccer players from a Dutch team intended to quantify training loads in relation to matches during a season, high metabolic load distances (between 565 m and 2472 m) were found from 4 days before the match day to the match day, reaching 6320 m in one week [27]. However, it is important to highlight that the specificity of exercise may constrain the load. In a study that analysed the metabolic distance in a single drill, variations between 357 m and 358 m were found [28]. However, this

study was conducted in university students and might not reflect the actual load per exercise associated with elite soccer training. Biomechanical loads as high intensity accelerations and high intensity decelerations are of extreme importance in team sports due to the high demands of the "start and stop" actions that might harm athletes' structures [29, 30].

Another study that collected data from 45 home matches over a three-season period found that the team completed a mean of 76 high intensity accelerations and 54 high intensity decelerations per match [31], which is in accordance with the present study, which found more weekly high intensity accelerations ($\sim$1000 n) than decelerations ($\sim$800 n). In contrast, a study conducted on 11 U-23 professional soccer players from the English Premier League found that players completed more high intensity decelerations (43 n) than high intensity accelerations (26 n) during a match [32]. This finding is in accordance with a systematic review of acceleration and deceleration profiles in elite team sports (including soccer) [30].

Regarding the number of impacts, the present study revealed a mean number of weekly team impacts of 1443.8. Between players, this value ranged between 1099.1 and 1617.6. Although little research has covered this topic [33], in the aforementioned study [32], it was found that during a match, the team suffered 6,172 impacts, which is higher than the values found in the present study if we consider the weekly acute impacts load.

Regarding overall accelerometry-based measures, our study revealed a simultaneous pattern between training monotony and training strain, by which it is assumed that when one increases or decreases, the other follows. This is in line with previous findings [15]. However, other work [17] has revealed contrary results, showing that higher training monotony is related to lower injury risk, while higher training strain values continued to be related to higher risk incidence.

The use of GPS devices to quantify elite athletes' external load variations throughout a season (mainly associated with distance-based measures) are well documented in recent literature [19, 34, 35]. However, research remains scarce on accelerometry-based measures such as high metabolic load, high intensity accelerations and decelerations, and impact variations across a full-season period. Therefore, it is difficult to compare our results with those of other studies because the majority of the research regarding these metrics considers only the match demands and does not consider weekly variations [30], which is not the case in the present study.

Moreover, there is a tendency to analyse these metrics in a match [36] and compare data between match halves instead of comparing periods of a season [31, 32, 37]. Such studies have revealed no significant differences between the two halves of a match for high intensity accelerations or high intensity decelerations, though a slight decrease was found from the first half to the second half for both measures. In the present study, moderate differences were found between the pre-season and the first and second halves of the season for the number of impacts. Meanwhile, corroborating the trend

observed in earlier studies of [31, 32], we found only small effect size differences for high intensity accelerations and decelerations between periods.

Considering variations in training monotony and strain, little evidence [22] exists supporting the type of calculations used in the present study for training monotony and strain (i.e., these calculations were applied through accelerometry-based measures instead of the well-established sRPE-based method) [18, 38]. Despite methodological differences, a previous study [19] found that training monotony tends to decrease across the season as the training strain seems to increase for the distance-based GPS device measures analysed. Although it is challenging to analyse training monotony and strain patterns across the season in the present study, it can be observed that more accentuated values tended to appear in the beginning and at the late phases of the season, while lower values were seen during the mid-season.

Regarding the differences between playing positions for acute load, training monotony, and training strain, only small effect size differences were found for all measures. Descriptive weekly acute loads of high metabolic load distances were greater for external defenders, midfielders, wingers, and strikers than for central defenders, while midfielders and wingers had significantly greater acute loads than strikers. Also, training strain values were greater for wingers than for central defenders and strikers, while no significant differences were found for training monotony. The acute loads of impacts were greater for external defenders than for central defenders, wingers, and strikers. Meanwhile, external and central defenders had greater training monotony values than strikers, while external defenders had greater training strain values than central defenders, wingers, and strikers. Also, central defenders had greater strain values than wingers and strikers, and midfielders had greater values than wingers and strikers. For high intensity accelerations, the external defenders had greater acute loads than midfielders. Furthermore, while no significant differences were found between positions in terms of training monotony, central defenders and wingers had greater strain values than strikers. For high intensity decelerations, external defenders had greater acute loads than central defenders, midfielders and strikers, and wingers had greater acute loads than central defenders and strikers. Also, while no significant differences were found between positions for training monotony, wingers had greater strain values than central defenders and strikers.

As for the abovementioned issues about studies considering only the match profiles of accelerometry-based measures, the same is true for differences between playing positions. However, in a study conducted on 46 professional soccer athletes, it was found that the central defenders had the lowest high metabolic load distances (1527 m) and the lowest number of high intensity accelerations (27 n) and decelerations (45 n) [39], which is in line with our results. However, the values found for high metabolic load for strikers contrast with the results of the present study, as they were significantly higher than what we reported.

Also, in a study comprised of 19 elite soccer players conducted over eight matches, it was found that the attackers had the lowest high intensity acceleration and high intensity deceleration values, while midfielders presented the highest values for both measures [40]. These findings are in line with our results, although it is difficult to compare them because the authors did not divide positions in the same way (i.e., they considered only defenders, midfielders, and attackers).

Also, as far as we know, no research has been done on weekly variations, between-period differences, and positional profiling for training monotony and training strain through accelerometry-based measures. For those reasons, in the present study, training monotony presented a between-week "w-shape" pattern across the full season for the overall accelerometry-based measures. Sudden large increases were observed for acute loads, training monotony, and training strain for the overall measures, especially in the late phases of in-season. Recent literature suggests that spikes of more than 10% in load do not necessarily cause injury [41]. Nevertheless, it seems to be preventive to control the load demands imposed on athletes and limit sudden increases or decreases in workloads between 10 and 15%, thus preventing injuries [42, 43].

The main evidence of the present study revealed that training monotony and strain were greater during the first weeks of the season and then dropped during the season and increasing again in the late phase of the season. Greater training monotony and strain were found in the pre-season than in the first and second halves of the season, but no significant differences were found for any other measures. Central defenders exhibited the lowest values of high metabolic load distances, while external defenders and midfielders presented the greatest numbers of impacts over the season.

The present study has some limitations, one of the most notable of which is the size of the sample. Also, we did not consider some potentially important metrics, such as player load, fatigue index, and dynamic stress. However, including too many variables could have hindered the analysis of this study. Despite these limitations, to the best of our knowledge, this was the first study to analyse variations of training monotony and training strain between periods of a full soccer season; it was also the first to observe variations between playing positions through accelerometry-based differences over an entire season. Future studies are needed to corroborate these findings, as it would be interesting to investigate the training monotony and strain differences between different playing formations.

CONCLUSIONS

The present study provided reference data of variation in external training loads for weekly periods within the annual season. Additionally, it was found that among professional male soccer players, greater training monotony and strain (including impacts and HMLD) occur during the pre-season than during the season, and these results were modulated by playing position. The current findings may help coaches and practitioners better regulate player load across the season in order to better prepare them for competition and reduce injury risk.

Conflict of interest

The authors declared no conflict of interest.

REFERENCES

1. Gabbett TJ, Nassis GP, Oetter E, Pretorius J, Johnston N, Medina D, et al. The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. Br J Sports Med. 2017; 51:1451–2.
2. Bourdon PC, Cardinale M, Murray A, Gastin P, Kellmann M, Varley MC, et al. Monitoring Athlete Training Loads: Consensus Statement. Int J Sports Physiol Perform. 2017; 12:S2-161-S2-170.
3. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and External Training Load: 15 Years On. Int J Sports Physiol Perform. 2019;14:270–3.
4. Halson SL. Monitoring Training Load to Understand Fatigue in Athletes. Sport Med. 2014;44:139–47.
5. Malone JJ, Lovell R, Varley MC, Coutts AJ. Unpacking the Black Box: Applications and Considerations for Using GPS Devices in Sport. Int J Sports Physiol Perform. 2017;12:S2-18-S2-26.
6. Buchheit M, Simpson BM. Player-Tracking Technology: Half-Full or Half-Empty Glass? Int J Sports Physiol Perform. 2017;12:S2-35-S2-41.
7. Castillo D, Raya-González J, Weston M, Yanci J. Distribution of External Load During Acquisition Training Sessions and Match Play of a Professional Soccer Team. J Strength Cond Res. 2019. https://doi.org/10.1519/jsc.0000000000003363.
8. Reche-Soto P, Cardona-Nieto D, Diaz-Suarez A, Bastida-Castillo A, Gomez-Carmona C, Garcia-Rubio J, et al. Player Load and Metabolic Power Dynamics as Load Quantifiers in Soccer. J Hum Kinet. 2019;69:259–69.
9. Gaudino P, Iaia FM, Strudwick AJ, Hawkins RD, Alberti G, Atkinson G, et al. Factors Influencing Perception of Effort (Session Rating of Perceived Exertion) during Elite Soccer Training. Int J Sports Physiol Perform. 2015;10:860–4.
10. Chmura P, Konefał M, Chmura J, Kowalczuk E, Zając T, Rokita A, et al. Match outcome and running performance in different intensity ranges among elite soccer players. Biol Sport. 2018;35:197–203.
11. Kasper K. Sports Training Principles. Curr Sports Med Rep. 2019;18:95–6.
12. Drew MK, Cook J, Finch CF. Sports-related workload and injury risk: simply knowing the risks will not prevent injuries: Narrative review. Br J Sports Med. 2016;50:1306–8.
13. Jaspers A, Kuyvenhoven JP, Staes F, Frencken WGP, Helsen WF, Brink MS. Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. J Sci Med Sport. 2018;21:579–85.
14. Blanch P, Gabbett TJ. Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. Br J Sports Med.

2016;50:471–5..

15. Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc. 1998;30:1164–8.

16. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. Br J Sports Med 2010;44:809–15.

17. Delecroix B, Mccall A, Dawson B, Berthoin S, Dupont G. Workload monotony, strain and non-contact injury incidence in professional football players. Sci Med Footb. 2019;3:105–8.

18. Lu D, Howle K, Waterson A, Duncan C, Duffield R. Workload profiles prior to injury in professional soccer players. Sci Med Footb. 2017;1:237–43.

19. Clemente FM, Clark C, Castillo D, Sarmento H, Nikolaidis PT, Rosemann T, et al. Variations of training load, monotony, and strain and dose-response relationships with maximal aerobic speed, maximal oxygen uptake, and isokinetic strength in professional soccer players. PLoS One. 2019;14:e0225522.

20. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. Br J Sports Med. 2010;44:809–15.

21. Windt J, Zumbo BD, Sporer B, MacDonald K, Gabbett TJ. Why do workload spikes cause injuries, and which athletes are at higher risk? Mediators and moderators in workload–injury investigations. Br J Sports Med. 2017;51:993–4.

22. Lazarus BH, Stewart AM, White KM, Rowell AE, Esmaeili A, Hopkins WG, et al. Proposal of a Global Training Load Measure Predicting Match Performance in an Elite Team Sport. Front Physiol. 2017;8. https://doi.org/10.3389/fphys.2017.00930.

23. Clemente FM, Silva AF, Clark CCT, Conte D, Ribeiro J, Mendes B, et al. Analyzing the Seasonal Changes and Relationships in Training Load and Wellness in Elite Volleyball Players. Int J Sports Physiol Perform. 2020; 15(5):731–740.

24. Beato M, Coratella G, Stiff A, Iacono A Dello. The Validity and Between-Unit Variability of GNSS Units (STATSports Apex 10 and 18 Hz) for Measuring Distance and Peak Speed in Team Sports. Front Physiol. 2018;9.

25. Beato M, de Keijzer K. The inter-unit and inter-model reliability of GNSS STATSports Apex and Viper units in measuring peak speed over 5, 10, 15, 20 and 30 meters. Biol Sport. 2019; 36:317–21.

26. Batterham AM, Hopkins WG. Making Meaningful Inferences about Magnitudes. Int J Sports Physiol Perform. 2006; 1:50–7.

27. Stevens TGA, de Ruiter CJ, Twisk JWR, Savelsbergh GJP, Beek PJ. Quantification of in-season training load relative to match load in professional Dutch Eredivisie football players. Sci Med Footb. 2017;1:117–25..

28. Beato M, De Keijzer KL, Carty B, Connor M. Monitoring fatigue during intermittent exercise with accelerometer-derived metrics. Front Physiol. 2019;10.

29. Osgnach C, Poser S, Bernardini R, Rinaldo R, Di Prampero PE. Energy cost and metabolic power in elite soccer: A new match analysis approach. Med Sci Sports Exerc. 2010;42:170–8.

30. Harper DJ, Carling C, Kiely J. High-Intensity Acceleration and Deceleration Demands in Elite Team Sports Competitive Match Play: A Systematic Review and Meta-Analysis of Observational Studies. Sport Med. 2019.

31. Dalen T, Jørgen I, Gertjan E, Geir Havard H, Ulrik W. Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. J Strength Cond Res. 2016; 30:351–9.

32. Russell M, Sparkes W, Northeast J, Cook CJ, Love TD, Bracken RM, et al. Changes in Acceleration and Deceleration Capacity Throughout Professional Soccer Match-Play. J Strength Cond Res. 2016; 30:2839–44.

33. Cummins C, Orr R, O'Connor H, West C. Global Positioning Systems (GPS) and Microtechnology Sensors in Team Sports: A Systematic Review. Sport Med. 2013;43:1025–42.

34. Bowen L, Gross AS, Gimpel M, Bruce-Low S, Li FX. Spikes in acute:chronic workload ratio (ACWR) associated with a 5–7 times greater injury rate in English Premier League football players: A comprehensive 3-year study. Br J Sports ed. 2019:1–9.

35. Andrzejewski M, Chmura J, Pluta B, Konarski JM. Sprinting activities and distance covered by top level Europa league soccer players. Int J Sport Sci Coach. 2015;10:39–50.

36. Arruda AFS, Carling C, Zanetti V, Aoki MS, Coutts AJ, Moreira A. Effects of a very congested match schedule on body-load impacts, accelerations, and running measures in youth soccer players. Int J Sports Physiol Perform. 2015;10:248–52.

37. Aughey RJ, Varley MC. Acceleration profiles in elite australian soccer. Int J Sports Med. 2013;34:282.

38. Comyns T, Flanagan EP. Applications of the session rating of perceived exertion system in professional Rugby union. Strength Cond J. 2013;35:78–85.

39. Tierney PJ, Young A, Clarke ND, Duncan MJ. Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. Hum Mov Sci. 2016; 49:1–8..

40. Wehbe GM, Hartwig TB, Duncan CS. Movement analysis of australian national league soccer players using global positioning system technology. J Strength Cond Res. 2014;28:834–42.

41. Gabbett TJ. Debunking the myths about training load, injury and performance: empirical evidence, hot topics and recommendations for practitioners. Br J Sports Med. 2018:bjsports-2018-099784.

42. Hulin BT, Gabbett TJ, Blanch P, Chapman P, Bailey D, Orchard JW. Spikes in acute workload are associated with increased injury risk in elite cricket fast bowlers. Br J Sports Med. 2014; 48:708–12

43. Li RT, Salata MJ, Rambhia S, Sheehan J, Voos JE. Does Overexertion Correlate With Increased Injury? The Relationship Between Player Workload and Soft Tissue Injury in Professional American Football Players Using Wearable Technology. Sports Health. 2020;12:66–73.