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

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

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INTRODUCTION

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

Through time-motion analysis, it was observed that, during a match, players execute ~30 sprints, comprising sequences of 2, 3, and 4 consecutive sprints, separated by rest intervals of 30, 45, or 60 s [4]. Match external load refers to the physical demands (i.e., accelerations [ACC] and decelerations [DEC], changes of direction [COD] and jumps) derived from position data or inertial measurement units [10]. Recently, Ribeiro et al. [8], using GPS technology,

reported that futsal players covered 3750 ± 1123 m, from which 135 ± 54 m were completed sprinting (> 18 km·h^{-1}). Moreover, players executed a great number of ACC (5 ± 2 n·min^{-1}), and DEC (5 ± 2 n·min^{-1}) relative to "court time" [8]. These data confirm the importance of high-intensity efforts during futsal match-play. Still, when it comes to a precise quantification of actions such as ACC, DEC, and COD, evidence is still scarce. More research is warranted since studies investigating these variables using wearable technology analysed only a small number of matches [8, 9].

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

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

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

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

MATERIALS AND METHODS
Study Design
A retrospective, observational, cohort study design was used. The match activity profile of elite male futsal players was collected using wearable technology (i.e., accelerometers [Catapult Innovation; Melbourne, Australia]) throughout the season 2019–2020 (20 games). Consistent with the *Liga Nacional de Fútbol Sala* (LNFS; 1st Division of Spain) rules, games lasted 40 min and consisted of two 20-min halves separated by a 10-min break. Only 10 of the team's 15 players were monitored, because of the GPS availability. The

study procedures did not influence or alter the match in any way. To compare teams' ranking, the following criteria were determined: "high": the top five teams in the league (excluding the monitored team) (n = 6 matches); "medium": the following five teams (n = 8 matches); "low": the bottom five teams of the league (n = 6 matches). Match outcome was classified as a "win" (n = 13 matches), "loss" (n = 5 matches) or "draw" (n = 2 matches). Due to the small number of "draws", this condition was excluded from the present study. Match location was referred to as "home" (n = 12) or "away" (n = 8).

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

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

Activity Profile Data: Variables of interest in this study included average and total player load (PL), PL per minute (PL·min^{-1}), high-intensity ACC (ACC$_{HI}$), high-intensity DEC (DEC$_{HI}$), explosive movements (EXPL-MOV), and high-intensity COD (COD$_{HI}$). PL consists of the sum of the accelerations across all axes of the internal tri-axial

accelerometer during movement (100 Hz), applying the established formula [21] and expressed as an arbitrary unit (a.u). PL·min^{-1} divides the accumulated PL by time, providing an intensity index and expressed as an a.u [22]. ACC$_{HI}$ refers to the total inertial movements registered in a forward acceleration vector within the high band (> 3.5 m·s^{-2}) and DEC$_{HI}$ corresponds to the total inertial movements in a deceleration vector within the high band (< -3.5 m·s^{-2}). COD$_{HI}$ represents total inertial movements registered in a rightward/leftward lateral vector within the high band (> 3.5 m·s^{-2}). Regarding the number (i.e., count) of ACC$_{HI}$, DEC$_{HI}$ and COD$_{HI}$, only high-intensity inertial movements were considered in the present research. EXPL-MOV encompass the total inertial movements irrespective of the direction (i.e., ACC, DEC and COD; jumps not included) within the medium and high bands (> 2.5 m·s^{-2}). Previous studies [23, 24] have already investigated and confirmed the validity and reliability of the aforementioned variables (i.e. ACC$_{HI}$, DEC$_{HI}$, EXPL-MOV, and COD$_{HI}$).

Statistical Analysis

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

RESULTS

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

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

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

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

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

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

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

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

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

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

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

DISCUSSION

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

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

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

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

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

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

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

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

CONCLUSIONS

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

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Conflict of interest declaration

The authors report no conflict of interest.

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