ORIGINAL SCIENTIFIC PAPER

Same Training for Everyone? Effects of Playing Positions on Physical Demands During Official Matches in Women's Handball

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Abstract

The purpose of this study was to analyze and compare the differences between playing positions on physical demands during official matches in women's handball. Twenty-two semi-professional female players (4 wings, 14 backs and 4 pivots) from the Spanish 2nd Division were monitored across 13 official home matches. Total distance covered (TDC), high-speed running distance (HSR), high-intensity breaking distance (HIBD), accelerations (ACC), decelerations (DEC) and PlayerLoad™ (PL) were collected in absolute and relative values (normalized by playing time) using a local positioning system (WIMU PRO™, Realtrack Systems S.L., Almería, Spain). Playing positions differences were determined by variance analysis one-way ANOVA with partial Eta-squared (ηp^2) or epsilon-squared (ε^2) and Cohen's effect size (ES). Wings covered more TDC (3414.5±1710.1 m), HSR (492.7±280.0 m) and HIBD (171.2±104.7 m) compared to backs and pivots ($p<0.05$; moderate-large effects). Wings also registered more total number of ACC (750.5±362.2) and PL (85.0±7.8 a.u.) compared to backs and pivots ($p<0.05$; moderate-large effects), whereas backs performed more ACC/min (19.9±1.1 $n \cdot min^{-1}$) than wings (18.9±1.4 $n \cdot min^{-1}$) and pivots (18.4±3.9 $n \cdot min^{-1}$) ($p<0.05$; moderate effects). In conclusion, physical demands differ between playing positions during official female competitions and these differences should be considered by practitioners to better prescribe and periodize training load and to design more individualized training programs.

Keywords: *handball; external load; tracking system; load monitoring; accelerometry*

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PLAYING POSITIONS AFFECTS PHYSICAL DEMANDS IN WOMEN'S HANDBALL
http://mjssm.me/?sekcija=article&artid=267

Cite this article: García-Sánchez, C., Navarro, M.N., Nieto-Acevedo, R., Cañadas-García, E., Rubia,, A. (2024) Same Training for Everyone? Effects of Playing Positions on Physical Demands During Official Matches in Women's Handball. *Montenegrin Journal of Sports Science and Medicine, 20 (1)*, 11–18. https://doi.org/10.26773/mjssm.240302

Received: 27 October 2023 | Accepted after revision: 09 January 2024 | Early access publication date: 01 February 2023 | Final publication date: 15 March 2024

Conflict of interest: None declared.

Introduction

Handball is an intermittent team-sport characterized by repeated high-intensity actions such as accelerations (ACC), decelerations (DEC), changes of direction (COD), sprints, jumps and throws with frequent and intense body contact against the opponents (Karcher and Buchheit, 2014). Consequently, the knowledge of the physical demands during official competitions is essential to maximize physical performance, minimize fatigue, and reduce injury risk (Karcher and Buchheit, 2014; Manchado et al., 2013). Nevertheless, previous research has shown that the physical demands greatly depending on gender, competition level and playing positions (García-Sánchez et al., 2023).

Traditionally, the assessment of physical demands in handball has been carried out mainly via time-motion analysis (TMA) (Manchado et al., 2013; Michalsik et al., 2014). However, the irruption of new tracking technologies with a good level of validity (Bastida-Castillo et al., 2019) and reliability (Luteberget et al., 2018), such as local positioning system (LPS) with ultra-wideband technology (UWB) and inertial measurement units (IMU), which record at 100 Hz, has created new opportunities to accurately investigate the external load in handball, especially to analyze high-intensity actions commencing from low velocity, such as a maximal acceleration from a stop position (Luteberget and Spencer, 2017; Wik et al., 2017).

At present, the investigation of the physical demands has focused predominantly on male handball players. Several studies have analyzed the physical demands in national (Font et al., 2021; Font et al., 2023) and international competitions (Cardinale et al., 2017; Manchado et al., 2020; Manchado et al., 2021), in simulated or friendly matches (Ortega-Becerra et al, 2020), and in training sessions (Corvino et al., 2014). Moreover, a recent systematic review (García-Sánchez et al., 2023) about external load during elite competitions reported that only 11.32% of the players included were female and the remaining 88.68% were male. Some studies developed with TMA showed that a female handball player covers from 2071 to 6943 meters during a match (Manchado et al., 2013; Michalsik et al., 2014; Bělka et al., 2016), specifically wings covered a moderately greater total distance than backs and pivots (Michalsik et al., 2014; Bělka et al., 2016). Recently, Luteberget and Spencer (2017) reported an average of 3.9±1.5 high-intensity events per minute during international matches, however backs showed the highest number followed by pivots and then by wings. Additionally, some studies indicated that PlayerLoad™ was similar for wings, backs and pivots (Luteberget and Spencer, 2017; Kniubaite et al., 2019).

As mentioned above, scientific evidence on physical demands in women's handball is currently limited. Consequently, this lack of knowledge represents a problem for practitioners and researchers because analyses of physical demands in male players may not be valid and accurate for prescribe training and manage workload in female players. Therefore, the aim of the present study was to analyze and compare the differences between playing positions on physical demands during official matches in women's handball.

Methods

Design

An observational study was conducted to analyze and compare the differences between playing positions on physical demands during official matches in women's handball. The reported results correspond to the average values of 13 official home matches from the Spanish 2nd Division during the 2021–2022 season (18th September 2021 – 2nd April 2022). In total, 153 individual LPS registers were collected (wings, n = 39; backs, n = 88; and pivots, n = 26). Players who participated for at least one minute in each game were included in the study (Wik et al., 2017). Goalkeepers were excluded (Ortega-Becerra et al, 2020).

Participants

Twenty-two semi-professional female handball players participated in the study. Playing positions were: wings (n = 4; age: 18.8±0.5 years; height: 162.0±3.8 cm; body mass: 55.5±4.3 kg), backs (n = 14; age: 20.9±3.6 years; height: 168.7±3.9 cm; body mass: 65.4±6.8 kg) and pivots (n = 4; age: 21.0±1.8 years; height: 171.3±4.8 cm; body mass: 79.1±11.0 kg). The weekly schedule consisted of 2 strength training sessions, 4 handball training sessions, and 1 match. All players were informed of the study requirements and provided written informed consent prior to the start of the study. Additionally, all the ethical procedures used in this study were in accordance with the Declaration of Helsinki (Harris & Atkinson, 2015) and were approved by the European University of Madrid Ethics Committee.

External load variables and procedures

A detailed description of each external load variable monitored is provided in Table 1. The LPS (WIMU PRO™, RealTrack System SL, Almería, Spain) was installed on the official handball court where the team played their home matches according to user manual and previous studies (Font et al., 2021; Font et al., 2023). The data was recording in real time and subsequently analysed using the manufacturer's specific software (SPRO™, version 958, RealTrack System SL, Almería, Spain). Raw data were exported in Excel format and imported into the statistical software for statistical analysis. Playing time was recorded only when the players were inside the court. Thereby, a specific software was used to calculate the perimeter of the court to determine the effective playing time. Thus, team time-outs (a maximum of three per team), periods when the game was interrupted (e.g., consultations between the referees or interruption to wipe the court) and the 2-minutes suspension were omitted.

Statistical analysis

Descriptive statistics are presented as means and standard deviations (M ± SD). Statistical significance level was set at $p<0.05$. The Kolmogorov-Smirnov test was performed to confirm data distribution normality and Levene's test for equality of variances. Playing positions differences were determined by variance analysis one-way ANOVA followed by Games–Howell or Tukey post hoc testing (parametric variables), or Kruskal-Wallis followed by the Dwass-Steel-Critchlow-Fligner test (non-parametric variables). Furthermore, two different effect sizes were calculated. For group effects, partial Eta-squared ($\eta p2$) or epsilon-squared (ε^2) was calculated with the following interpretation: small (0.010–0.059), moderate (0.060–0.139), and large effect (>0.14) (Cohen, 1988). For the post-hoc analysis, Cohen's d (ES) was calculated and interpreted using Hopkins' categorization criteria, where 0.2, 0.6, 1.2 and >2 are considered small, moderate, large and very large effects, respectively (Hopkins et al., 2009). Data analysis was performed using SPSS for Windows (Version 26, IBM Corp., Armonk, NY, USA).

DOI 10.26773/mjssm.240302

Table 1. Description of external load variables.

Variable	Unit	Description
Total distance covered (TDC)	m	Total distance covered by the player
Total distance covered/min (TDC/min)	m·min^{-1}	Total distance covered per minute by the player
High speed running (HSR)	m	Total distance covered above 18.1 km/h
High speed running/min (HSR/min)	m·min^{-1}	Total distance covered per minute above 18.1 km/h
High intensity break distance (HIBD)	m	Total distance covered with deceleration above 2 m·s^{-2}
High intensity break distance/min (HIBD/min)	m·min^{-1}	Total distance covered per minute with deceleration above 2 m·s^{-2}
Total distance covered by speed zones	m	Total distance covered by the player at different speed zones during the match: zone 1 (0–6.0 km·h^{-1}), zone 2 (6.1–12.0 km·h^{-1}), zone 3 (12.1–18.0 km·h^{-1}), zone 4 (18.1–21.0 km·h^{-1}) and zone 5 (> 21.1 km·h^{-1})
Accelerations	count	Total number of accelerations performed by the player
Accelerations/min	count·min^{-1}	Total number of accelerations per minute performed by the player
Accelerations by intensity zones	count	Total number of accelerations performed by the player at different intensities during the match: zone 1 (0 to 1 m·s^{-2}), zone 2 (1 to 2 m·s^{-2}), zone 3 (2 to 3 m·s^{-2}), zone 4 (3 to 4 m·s^{-2}), zone 5 (4 to 5 m·s^{-2}) and zone 6 (5 to 6 m·s^{-2})
Decelerations	count	Total number of decelerations performed by player
Decelerations/min	count·min–1	Total number of decelerations per minute performed by player
Decelerations by intensity zones	count	Total number of decelerations performed by the player at different intensities during the match: zone 1 (-1 to 0 m·s^{-2}), zone 2 (-2 to -1 m·s^{-2}), zone 3 (-3 to -2 m·s^{-2}), zone 4 (-4 to -3 m·s^{-2}), zone 5 (-5 to -4 m·s^{-2}) and zone 6 (-6 to -5 m·s^{-2})
PlayerLoad (PL)	a.u.	Is a vector magnitude expressed as the square root of the sum of the squared instantaneous rates of change in acceleration in each one of the three planes divided by 100, according to the next formula: $PlayerLoad_{t=n} \sum_{t=0}^{t=n} \sqrt{\frac{(Z_{t=i+1} - Z_{t=i})^2 + (X_{t=i+1} - X_{t=i})^2 + (Y_{t=i+1} - Y_{t=i})^2}{100}}$
PlayerLoad/min (PL/min)	a.u.·min–1	Is a vector magnitude expressed as the square root of the sum of the squared instantaneous rates of change in acceleration in each one of the three planes divided by 100 per minute

Results

Descriptive values and statistical differences for the external load variables according to playing positions are presented in Table 2. There were differences with moderate to large effect size between playing positions in TDC ($p<0.001$; $\eta p2 = 0.200$), TDC/min ($p=0.002$; $\varepsilon^2 = 0.08$), HSR ($p<0.001$; $\varepsilon^2 = 0.406$), HSR/min ($p<0.001$; $\varepsilon^2 = 0.412$), HIBD ($p<0.001$; $\eta p2 = 0.374$) and HIBD/min ($p<0.001$; $\varepsilon^2 = 0.135$). Wings covered largely more distance (3414.5±1710.1 m) compared to backs (2301.6±1119.0 m) and pivots (1449.6±1194.6 m)

Table 2. External load variables according to playing positions.

Variables	Backs	Pivots	Wings	Position Group Effect		
				p value	ηp^2	ε^2
TDC (m)	2301.6±1119.0 ^{pp}	1449.6±1194.6	3414.5±1710.1 $^{bbb\ ppp}$	<0.001	0.200	-
TDC/min (m·min^{-1})	81.3±13.1	83.9±21.3	85.0±7.8 ^{bb}	0.002	-	0.080
HSR (m)	105.8±75.5 ^{p}	56.9±41.4	492.7±280.0 $^{bbb\ ppp}$	<0.001	-	0.406
HSR/min (m·min^{-1})	4.1±3.1	4.6±5.5	12.0±3.5 $^{bbb\ ppp}$	<0.001	-	0.412
HIBD (m)	76.2±44.0 ^{pp}	33.0±21.1	171.2±104.7 $^{bbb\ ppp}$	<0.001	0.374	-
HIBD/min (m·min^{-1})	2.9±1.5	2.8±2.4	4.2±1.9 $^{bbb\ pp}$	<0.001	-	0.135
Accelerations (n)	592.0±309.7 ^{pp}	357.6±343.7	750.5±362.2 $^{b\ ppp}$	<0.001	0.128	-
Accelerations/min (n·min^{-1})	19.9±1.1 $^{ppp\ w}$	18.4±3.9	18.9±1.4	<0.001	-	0.099
Decelerations (n)	456.7±272.6 ^{pp}	261.2±254.0	541.1±307.6 ^{ppp}	<0.001	0.096	-
Decelerations/min (n·min^{-1})	15.6±3.6 ^{ww}	14.3±4.4	13.4±3.4	0.005	-	0.070
PlayerLoad (a.u.)	38.4±19.2 ^{p}	25.1±17.7	57.1±30.4 $^{bbb\ ppp}$	<0.001	0.186	-
PlayerLoad/min (a.u.·min^{-1})	1.8±0.7	1.9±0.9	1.9±0.8	0.86	-	0.001

Note. Significance level is indicated by the number of symbols: one symbol for p<0.05, two for p<0.01, and three for p<0.001; b significant differences with regard to backs; p significant differences with regard to pivots; w significant differences with regard to wings; TDC = Total distance covered; HSR = High-speed running (distance >18.1 km/h); HIBD = High Intensity Break Distance; a.u. = Arbitrary units.

(p<0.001, ES = 0.85; p<0.001, ES = 1.50, respectively). Furthermore, backs covered moderately more TDC than pivots (p<0.01, ES = 0.65). Wings covered slightly more TDC/min (85.0±7.8 m·min−1) than backs (81.3±13.1 m·min−1) (p<0.01; ES = 0.26). Additionally, wings covered largely more HSR distance (492.7±280.0 m) compared to backs (105.8±75.5 m) and pivots (56.9±41.4 m) (p<0.001, ES = 2.52; p<0.001, ES = 2.84, respectively). Also, backs covered slightly more HSR than pivots (p=0.011, ES = 0.31). Finally, HIBD was significantly different according to playing positions (p<0.001; ηp2 = 0.374). Wings covered largely HIBD (171.2±104.7 m) than backs (76.2±44.0 m) and pivots (33.0±21.1 m) (p<0.001, ES = 1.50; p < 0.001, ES = 2.19, respectively). Also, backs covered moderately more HIBD than pivots (p<0.01, ES = 0.68).

Figure 1 shows the total distance covered at different speeds zones according to playing positions. In zone 1 wings and backs covered largely more distance (1129.3±576.3; 900.3±467.9 m, respectively) than pivots (529.0±484.2 m) (p<0.001, ES = 1.20; p=0.003, ES = 0.74, respectively). Also, in zone 2 wings and backs covered largely more distance (936.8±472.7; 774.7±384.4 m, respectively) than pivots (441.4±342.6 m) (p<0.001, ES = 1.23; p=0.003, ES = 0.82, respectively). Moreover, in zones 3, 4 and 5 wings covered largely more distance (987.4±496.8; 240.0±140.9; 121.0±78.1, respectively) than backs (548.7±290.5; 57.5±43.8; 20.3±21.7, respectively) and pivots (436.4±380.3; 36.3±26.9; 6.5±8.5, respectively) (p<0.001, ES >1.2). Additionally, in zone 5 backs covered largely more distance than pivots (p<0.001).

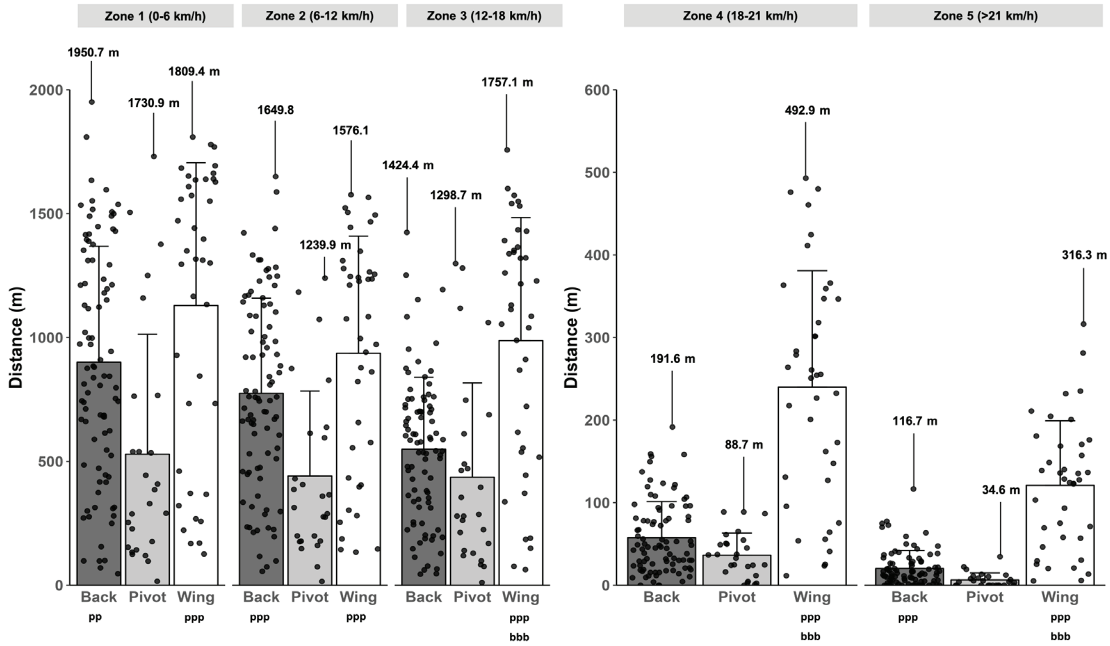

Figure 1. Total distance covered at different speed zones according to playing positions. Significance level is indicated by the number of symbols: one symbol for p < 0.05, two for p < 0.01, and three for p < 0.001; p significant differences compared to pivots; b significant differences compared to backs.

There were differences with moderate effect sizes between playing positions in the number of ACC (p<0.001, ηp2 = 0.128), decelerations (p<0.001, ηp2 = 0.096), ACC/min (p<0.001, ε^2 = 0.099) and DEC/min (p=0.005, ε^2 = 0.070). Wings performed slightly more number of ACC (750.5±362.2) compared to backs (592.0±309.7) and largely more compared pivots (357.6±343.7) (p=0.036, ES = 0.48; p<0.001, ES = 1.19, respectively). Also, backs performed moderately more ACC than pivots (p=0.005, ES = 0.71). Additionally, wings and backs performed moderately more number of DEC (541.1±307.6; 456.7±272.6, respectively) than pivots (261.2±254.0) (p<0.001, ES = 1.00; p=0.006, ES = 0.70, respectively). In contrast, backs performed moderately more ACC/min (19.9±1.1 n·min−1) than wings (18.9±1.4 n·min−1) and pivots (18.4±3.9 n·min−1) (p=0.024, ES = 0.50; p<0.001, ES = 0.82, respectively). In addition, backs performed moderately more DEC/min (15.6±3.6 n·min−1) than wings (13.4±3.4 n·min−1) (p=0.007, ES = 0.58).

Figure 2 present the total number of ACC by intensity zones according to playing positions. In zones 1 and 2, wings (466.3±226.4; 169.3±87.6, respectively) and backs (393.4±219.3; 139.7±73.3, respectively) performed moderately more ACC than pivots (244.3±268.2; 81.6±61.8, respectively) (p<0.05, ES = 0.64-1.16). Also, in zones 3 and 4, wings (74.4±38.0; 24.4±13.3, respectively) and backs (46.3±23.0; 9.6±6.5, respectively) performed moderately to large more ACC than pivots (25.9±17.3; 3.0±2.6, respectively) (p<0.01, ES = 1.04-2.54). Finally, in zones 5 and 6, wings (7.5±6.9; 4.5±5.7, respectively) performed largely more ACC than backs (2.3±3.2; 1.0±1.9, respectively) and pivots (1.1±1.9; 0.5±0.8, respectively) (p<0.001, ES = 1.07-1.48).

Figure 3 present the total number of DEC by intensity zones according to playing positions. In zones 1 and 2, wings (338.1±194.4; 121.9±75.0, respectively) and backs (307.2±196.7; 100.8±60.4, respectively) performed moderately more DEC than pivots (179.8±196.6, 60.3±50.2, respectively) (p<0.05, ES = 0.64-0.97). In zones 3, 4, 5 and 6 wings (48.5±25.8; 18.7±11.5; 7.1±5.8; 2.9±3.2, respective-

 DOI 10.26773/mjssm.240302

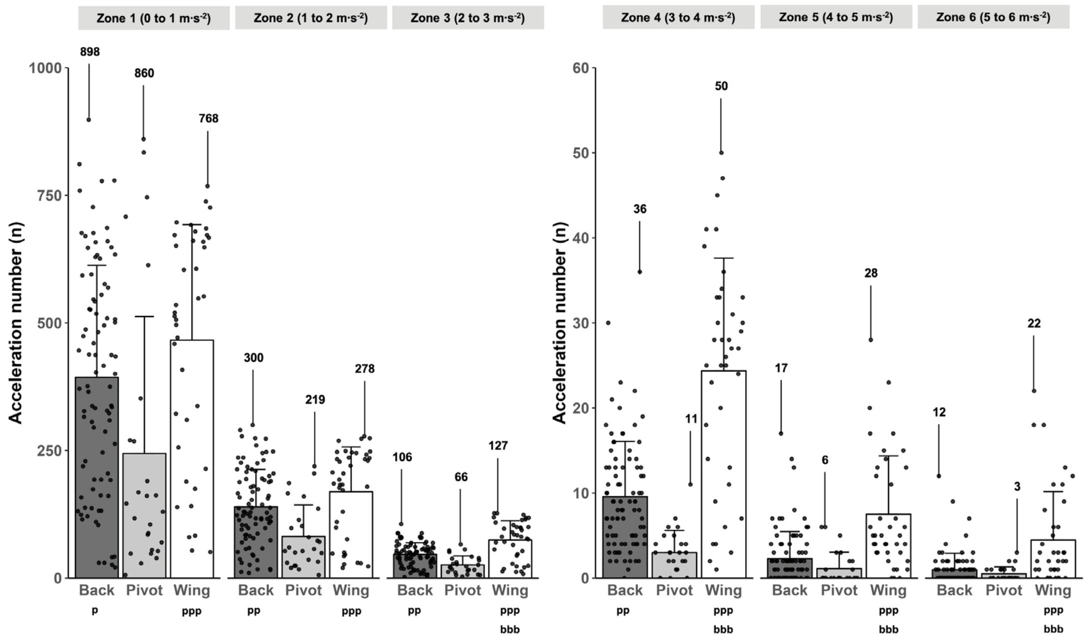

Figure 2. Number of accelerations performed at different intensity zones according to playing positions. Significance level is indicated by the number of symbols: one symbol for p < 0.05, two for p < 0.01, and three for p < 0.001; p significant differences compared to pivots; b significant differences compared to backs.

ly) performed moderately to large more DEC than backs (35.9±18.3; 10.4±6.6; 2.1±2.2; 0.6±1.5, respectively) and pivots (16.0±10.4; 3.1±2.5; 0.6±0.9; 0.3±0.6, respectively) ($p<0.01$, ES = 0.64-2.00). Additionally, in zones 3, 4 and 5 backs performed moderately more DEC than pivots ($p<0.001$, ES = 0.45-1.01).

Differences with large effect sizes between playing positions were evident in PL ($p<0.001$; $\eta p2 = 0.186$). Wings registered moderately more PL (85.0±7.8 a.u.) compared to backs (38.4±19.2 a.u.) and largely more than pivots (25.1±17.7 a.u.) ($p<0.001$, ES = 0.83; $p<0.001$, ES = 1.42, respectively). Moreover, backs registered moderately more PL than pivots ($p=0.023$, ES = 0.59). No significant differences in PL/min between playing positions were found ($p=0.86$, $\varepsilon^2 = 0.001$).

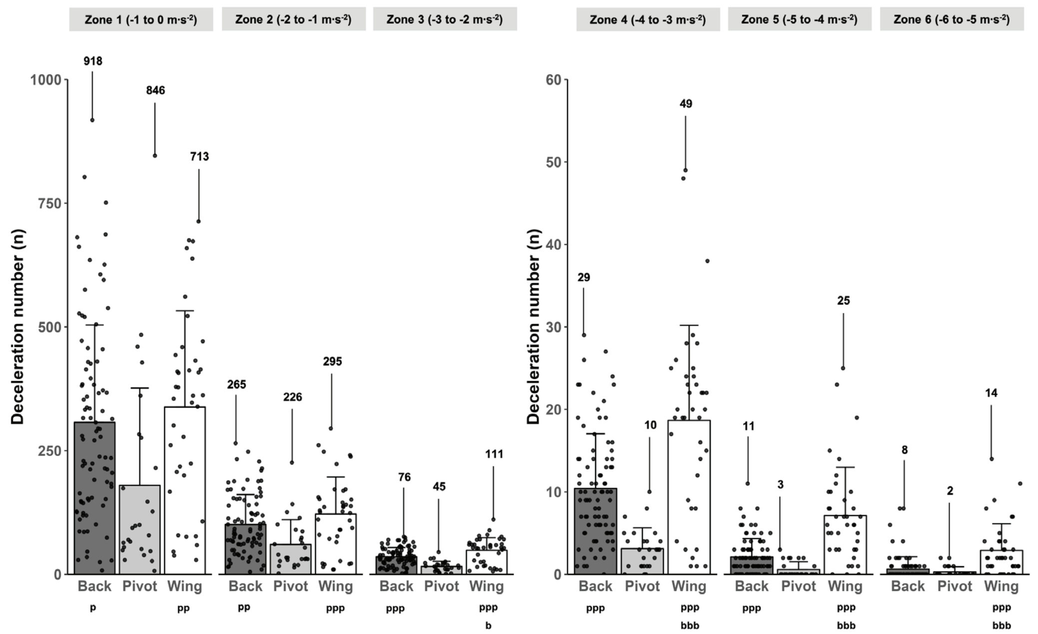

Figure 3. Number of decelerations performed at different intensity zones according to playing positions. Significance level is indicated by the number of symbols: one symbol for p < 0.05, two for p < 0.01, and three for p < 0.001; p significant differences compared to pivots; b significant differences compared to backs.

Discussion

To our knowledge, this is the first study that analyze different external load variables using LPS with IMU technology in semi-professional female handball players during a complete season. Our results confirmed that the external load was significantly different between playing positions, except in PL/minute. Specifically, wings presented the highest external load, while pivots showed the lowest values.

In relation to distance variables, wings covered the highest TDC and TDC/min, while pivots showed the lowest values. Similar results were found in previous studies developed in female players with TMA (Michalsik et al., 2014; Bělka et al., 2016) and in male players with LPS (Font et al., 2021; Font et al., 2023; Cardinale et al, 2017; Manchado et al., 2021). These differences between the pivots and the other playing positions, mainly in total distance covered, could be explained by the unlimited substitutions in handball. Many teams use pivots only in offensive phase for various reasons, such as a lack of defensive ability or load management (Font et al., 2021; Font et al., 2023).

Similarly, previous research has observed that all players covered more distance at low velocities (walking and jogging), either in studies performed with TMA (Manchado et al., 2013; Michalsik et al., 2014) or LPS (Saal et al., 2023; Font et al., 2021; Cardinale et al, 2017; Manchado et al., 2021). Specifically, our results show that during the competition most of the meters were covered at low (6.1–12.0 km·h−1) or very low speed (0–6.0 km·h−1). This fact confirm that handball is an intermittent sport, characterized by periods of long low intensity movements interrupted by short high intensity actions (Karcher and Buchheit, 2014; Manchado et al., 2013). Additionally, wings covered the highest distance in zone 4 and 5, while pivots showed the lowest values. Also, wings covered largely more HSR/minute (12.0±3.5 m·min−1) than the other playing positions. These results are consistent with those of previous studies (Font et al., 2021; Font et al., 2023; Cardinale et al, 2017; Manchado et al., 2020; Manchado et al., 2021) and could be related to the increased participation of wings players in the counter-attack phases (Michalsik et al., 2015). This suggests that wings need different physical training than the other positions, especially emphasizing on-court sprint training (e.g., repeated sprint training or sprint interval training) (Buchheit and Laursen, 2013) and specific strength training to reduce hamstring strain injury (Duhig et al., 2016) and enhance HSR performance (Karcher and Buchheit, 2014; Manchado et al., 2013).

Wings covered largely more HIBD and HIBD/minute than the other playing positions. These differences may be associated with the strong decelerations from a high velocity that they must perform after each counter-attack action. Thus, HIBD are associated with intense eccentric contractions that produce high neuromuscular fatigue and tissue damage, especially if these high braking forces cannot be dissipated and distributed efficiently (Harper et al., 2019; Harper et al., 2022). Also, a reduced deceleration capacity has been identified as a risk factor for non-contact ACL injuries (Boden et al., 2009). Therefore, the technical staff should design optimal training interventions to develop robust musculoskeletal structures that efficiently attenuate high braking eccentric forces and reduce the risk of severe injuries (Harper et al., 2019; Harper et al., 2022; McBurnie et al., 2022).

Regarding accelerometry data, wings performed higher total number of ACC and DEC, followed by backs and pivots. However, when these values were normalized according to the time the players spend on the court (n·min-1), backs performed moderately more ACC and DEC per minute than the other positions. Additionally, wings performed moderately more high-intensity ACC and DEC (>3 m·s−2) than backs and pivots. These results could also be related to the specific technical requirements of each position. Wings perform more counter-attack actions than the other positions, so it seems reasonable to assume that they perform a greater total number of accelerations per game (Michalsik et al., 2015). Backs have a greater deceleration load because they have the main responsibility of building up the positional attack, which is characterized by a constant piston movement. Furthermore, like previous research (Saal et al., 2023), pivots showed the lowest values, because their technical actions are mainly associated with a high isometric force production against the opponent. In contrast, our findings are in opposition with a recent study conducted with elite male players, in which all players present similar values of ACC and DEC (Font et al., 2021). A possible explanation for this difference could reside in the combination of two factors: (1) sample characteristics (male vs. female players) and (2) competition level (elite vs. semi-professional). Therefore, our results indicate that wings and backs should incorporate specific acceleration-deceleration training methods and well-developed muscle strength with two purposes: (1) to ensure these players perform at high-intensity throughout the entire match and (2) to "mechanically protect" players from these damaging consequences of high-intensity decelerations (Harper et al., 2019). Nonetheless, despite the pivots performed lower total number of ACC and DEC compared to backs and wings, they should also be prepared to support these actions during the competition. Thus, they should also incorporate that type of training.

Associated with PlayerLoad variables, wings registered moderately more PL compared to backs and largely more than pivots. Nevertheless, when these values were standardized by playing time (a.u.·min-1) there were no substantial differences according to playing positions. Our results could be explained in part by the higher playing time for wings compared to pivots, due to there is a direct relationship between time on court and external load (in absolute values) accumulated by players. On the other hand, it is difficult to compare our results with other similar studies (Luteberget and Spencer 2017; Wik et al., 2017; Font et al., 2021; Kniubaite et al., 2019), because each trademark uses a different algorithm to calculate this variable (Wik et al., 2017). Only the research conducted by Font et al. (2021), which used the same LPS device as our study, found similar PL/min values for all playing positions. However, their values are slightly lower than ours (≈1.1±0.2 vs. ≈1.9±0.8 a.u.·min-1, respectively). We hypothesised that this difference could be explained by the two factors mentioned above (sample characteristics and competition level). In contrast, Luteberget and Spencer (2017) indicated that backs and pivots showed the highest PL/min values. These results may be due to a different competition level compared to our study. Nonetheless, some caution must be taken when interpreting results of PL, because some researchers indicate that PL calculation methods present many inconsistencies and lack clear and complete information (Wik et al., 2017; Bredt et al., 2020).

Although the current study provides usefulness information for handball coaches and strength and conditioning professionals, some limitations should be mentioned. Firstly, only one female team and only home matches were investigated. Secondly, LPS and IMU may not reflect (tend to underestimate) the real physical demands of pivots, because these players usually perform some high-intensity actions (e.g., blocks and screenings) that not produce a displacement or acceleration. Thirdly, the analysis of specialist players (offensive or defensive) and goalkeepers was not performed. Lastly, differ-

 DOI 10.26773/mjssm.240302

ent contextual factors could have influenced our results, such as match location, match outcome, score differential, level of the opponent, competition level and player rotation strategy.

In conclusion, the present study indicates that external load experienced by semi-professional female handball players during official competitions are affected by playing positions. Wings registered the highest external load values, followed by backs and by pivots. Additionally, wings are characterized by a high volume of total distance and high-speed running distance (>18 km/h), a higher number of high-intensity ACC and DEC (>3 m·s−2), and a higher PlayerLoad. In contrast, backs are also distinguished by the highest number of ACC and DEC per minute. Therefore, the findings of the present study could provide reference values for technical staff to better prescribe and periodize weekly training load and to design and implement more individualized physical training programs for each playing position (e.g., wings should emphasize repeated sprint training or sprint interval training to enhance HSR performance, backs should develop the capacity of muscles and tendons to attenuate high eccentric forces associated with repeated decelerations and pivots should increase their maximal force to support heavy contacts against the opponents). Furthermore, handball coaches should incorporate different strength training methods (e.g., unilateral and bilateral exercises, single- and multi-joint exercises, eccentric and accentuated eccentric exercises, plyometric exercises, and weightlifting movements and their derivatives) and other training strategies (e.g., single- and double-leg landing stabilisation exercises, pre-planned and unanticipated COD and rapid decelerations from a high velocity) to decelerate efficiently and subsequently reduce injury risk and maximize physical performance. Future studies should investigate the impact of contextual factors on the external load to provide a more comprehensive analysis of the game in female players.

Acknowledgements
The authors would like to thank all the players and technical staff of Balonmano iKasa for their predisposition and participation.

Conflicts of Interest
The authors declare no conflict of interest.

References
Bastida-Castillo, A., Gómez-Carmona, C., De la Cruz-Sánchez, E., Reche-Royo, X., Ibáñez, S., & Pino Ortega, J. (2019). Accuracy and Inter-Unit Reliability of Ultra-Wide-Band Tracking System in Indoor Exercise. *Applied Sciences*, *9*(5), 939. http://dx.doi.org/10.3390/app9050939

Bělka, J., Hůlka, K., Šafář, M., & Weisser, R. (2016). External and internal load of playing positions of elite female handball players (U19) during competitive matches. *Acta Gymnica*, *46*(1), 12-20. doi: 10.5507/ag.2015.025

Boden, B. P., Torg, J. S., Knowles, S. B., & Hewett, T. E. (2009). Video analysis of anterior cruciate ligament injury: abnormalities in hip and ankle kinematics. *The American journal of sports medicine*, *37*(2), 252–259. https://doi.org/10.1177/0363546508328107

Bredt, S. D. G. T., Chagas, M. H., Peixoto, G. H., Menzel, H. J., & de Andrade, A. G. P. (2020). Understanding Player Load: Meanings and Limitations. *Journal of human kinetics*, *71*, 5–9. https://doi.org/10.2478/hukin-2019-0072

Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle. Part II: anaerobic energy, neuromuscular load and practical applications. *Sports medicine (Auckland, N.Z.)*, *43*(10), 927–954. https://doi.org/10.1007/s40279-013-0066-5

Cardinale, M., Whiteley, R., Hosny, A. A., & Popovic, N. (2017). Activity Profiles and Positional Differences of Handball Players During the World Championships in Qatar 2015. *International journal of sports physiology and performance*, *12*(7), 908–915. https://doi.org/10.1123/ijspp.2016-0314

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd. Ed.) Hillsdale, NJ: Lawrence Earlbaum Associates

Corvino, M., Tessitore, A., Minganti, C., & Sibila, M. (2014). Effect of Court Dimensions on Players' External and Internal Load during Small-Sided Handball Games. *Journal of sports science & medicine*, *13*(2), 297–303.

Duhig, S., Shield, A. J., Opar, D., Gabbett, T. J., Ferguson, C., & Williams, M. (2016). Effect of high-speed running on hamstring strain injury risk. *British journal of sports medicine*, *50*(24), 1536–1540. https://doi.org/10.1136/bjsports-2015-095679

Font Ribas, R., Karcher, C., Loscos-Fàbregas, E., Altarriba-Bartés, A., Peña, J., Vicens-Bordas, J., Mesas, J. A., & Irurtia, A. (2023). The effect of training schedule and playing positions on training loads and game demands in professional handball players. *Biology of sport*, *40*(3), 857–866. https://doi.org/10.5114/biolsport.2023.121323

Font Ribas, R., Karcher, C., Reche, X., Carmona, G., Tremps, V., & Irurtia, A. (2021). Monitoring external load in elite male handball players depending on playing positions. *Biology of sport*, *38*(3), 475–481. https://doi.org/10.5114/biolsport.2021.101123

García-Sánchez, C., Navarro, R. M., Karcher, C., & de la Rubia, A. (2023). Physical Demands during Official Competitions in Elite Handball: A Systematic Review. *International journal of environmental research and public health*, *20*(4), 3353. https://doi.org/10.3390/ijerph20043353

Harper, D. J., Carling, C., & Kiely, J. (2019). High-Intensity Acceleration and Deceleration Demands in Elite Team Sports Competitive Match Play: A Systematic Review and Meta-Analysis of Observational Studies. *Sports medicine (Auckland, N.Z.)*, *49*(12), 1923–1947. https://doi.org/10.1007/s40279-019-01170-1

Harper, D. J., McBurnie, A. J., Santos, T. D., Eriksrud, O., Evans, M., Cohen, D. D., Rhodes, D., Carling, C., & Kiely, J. (2022). Biomechanical and Neuromuscular Performance Requirements of Horizontal Deceleration: A Review with Implications for Random Intermittent Multi-Directional Sports. *Sports medicine (Auckland, N.Z.)*, *52*(10), 2321–2354. https://doi.org/10.1007/s40279-022-01693-0

Harriss, D. J. and Atkinson, G. (2015) Ethical standards in sport and exercise science research: 2016 update. *International Journal of Sports Medicine 36*(14), 1121–1124.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and science in sports and exercise*, *41*(1), 3–13. https://doi.org/10.1249/MSS.0b013e31818cb278

Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports* *medicine (Auckland, N.Z.)*, *44*(6), 797–814. https://doi.org/10.1007/s40279-014-0164-z

Kniubaite, A., Skarbalius, A., Clemente, F. M., & Conte, D. (2019). Quantification of external and internal match loads in elite female team handball. *Biology of sport*, *36*(4), 311–316. https://doi.org/10.5114/biolsport.2019.88753

Luteberget, L. S., & Spencer, M. (2017). High-Intensity Events in International Women's Team Handball Matches. *International journal of sports physiology and performance*, *12*(1), 56–61. https://doi.org/10.1123/ijspp.2015-0641

Luteberget, L. S., Holme, B. R., & Spencer, M. (2018). Reliability of Wearable Inertial Measurement Units to Measure Physical Activity in Team Handball. *International journal of sports physiology and performance*, *13*(4), 467–473. https://doi.org/10.1123/ijspp.2017-0036

Manchado, C., Pers, J., Navarro, F., Han, A., Sung, E., & Platen, P. (2013). Time-motion analysis in women's team handball: Importance of aerobic performance. *Journal of Human Sport and Exercise*, *8*(2), 376–390. https://doi.org/10.4100/jhse.2012.82.06

Manchado, C., Pueo, B., Chirosa-Rios, L. J., & Tortosa-Martínez, J. (2021). Time-Motion Analysis by Playing Positions of Male Handball Players during the European Championship 2020. *International journal of environmental research and public health*, *18*(6), 2787. https://doi.org/10.3390/ijerph18062787

Manchado, C., Tortosa Martínez, J., Pueo, B., Cortell Tormo, J. M., Vila, H., Ferragut, C., Sánchez Sánchez, F., Busquier, S., Amat, S., & Chirosa Ríos, L. J. (2020). High-Performance Handball Player's Time-Motion Analysis by Playing Positions. *International journal of environmental research and public health*, *17*(18), 6768. https://doi.org/10.3390/ijerph17186768

Manchado, C., Tortosa-Martínez, J., Vila, H., Ferragut, C., & Platen, P. (2013). Performance factors in women's team handball: physical and physiological aspects--a review. *Journal of strength and conditioning research*, *27*(6), 1708–1719. https://doi.org/10.1519/JSC.0b013e3182891535

McBurnie, A. J., Harper, D. J., Jones, P. A., & Dos'Santos, T. (2022). Deceleration Training in Team Sports: Another Potential 'Vaccine' for Sports-Related Injury?. *Sports medicine (Auckland, N.Z.)*, *52*(1), 1–12. https://doi.org/10.1007/s40279-021-01583-x

Michalsik, L. B., Aagaard, P., & Madsen, K. (2015). Technical activity profile and influence of body anthropometry on playing performance in female elite team handball. *Journal of strength and conditioning research*, *29*(4), 1126–1138. https://doi.org/10.1519/JSC.0000000000000735

Michalsik, L. B., Madsen, K., & Aagaard, P. (2014). Match performance and physiological capacity of female elite team handball players. *International journal of sports medicine*, *35*(7), 595–607. https://doi.org/10.1055/s-0033-1358713

Ortega-Becerra, M., Belloso-Vergara, A., & Pareja-Blanco, F. (2020). Physical and Physiological Demands During Handball Matches in Male Adolescent Players. *Journal of human kinetics*, *72*, 253–263. https://doi.org/10.2478/hukin-2019-0111

Saal, C., Baumgart, C., Wegener, F., Ackermann, N., Sölter, F., & Hoppe, M. W. (2023). Physical match demands of four LIQUI-MOLY Handball-Bundesliga teams from 2019-2022: effects of season, team, match outcome, playing position, and halftime. *Frontiers in sports and active living*, *5*, 1183881. https://doi.org/10.3389/fspor.2023.1183881

Wik, E. H., Luteberget, L. S., & Spencer, M. (2017). Activity Profiles in International Women's Team Handball Using PlayerLoad. *International journal of sports physiology and performance*, *12*(7), 934–942. https://doi.org/10.1123/ijspp.2015-0732

 DOI 10.26773/mjssm.240302