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Exploring External Load Metrics in Team Handball: A Study of Europe's Under-20 Male Championship

Exploración de las métricas de carga externa en el balonmano de equipo: Un estudio del Campeonato Europeo Masculino Sub-20

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Abstract

The objective assessment of external physical loads has become promising in better understanding players' match loads and responses. However, there is a lack of consensus on the metrics used along with limited information on this topic in elite handball. This study investigated differences in conventional and novel external load metrics according to playing positions. Methods: 27 matches of EHF Euro M20 2022 were used, with a total of 711 player match observations recorded. The data series were collected using a local positioning system (LPS) integrated with inertial measurement unit (IMU) devices. Kinematic variables: match-jerk, match-Dynamic Stress Load (match-DSL), distance covered, distance covered at high speed (HSR distance). Despite the lack of handball-specific validation, differences between studied positions were found in all variables. Greater sensibility seems possible based on the match-DSL compared to match-jerk. Accordingly, Backs exhibited the highest match-DSL values. Divergently, the Wings covered more distance at total and high-speed running while showing lower match-DSL relative to the Backs. The Line Players had similar HSR distances to Backs while covering lower total distances. Future studies are needed to explore the validity of the available metrics and arbitrary parameters, as well as comparing those variables with internal-load variables.
Keywords: handball; jerk; DSL; accelerometry; physical performance

Resumen

La evaluación objetiva de las cargas físicas externas se ha convertido en algo promisorio para mejor comprender la carga y la respuesta de un jugador. Sin embargo, hay una falta de consenso sobre las métricas a utilizar junto con información limitada sobre este tema en el balonmano de élite. Este estudio investigó las diferencias con métricas tradicionales y nuevas de carga mecánica externa según las posiciones de juego. Métodos: se utilizaron 27 partidos de la EHF Euro M20 2022, con un total de 711 muestras de jugadores registradas. Data series se recopiló con un sistema de posicionamiento local (LPS) con dispositivos de unidad de medición inercial (IMU) integrados. Variables cinemáticas: match-jerk, match-Dynamic Stress Load (match-DSL), la distancia recorrida y la distancia recorrida a alta velocidad. A pesar de carecer de validación contextual en balonmano, se encontraron diferencias entre las posiciones estudiadas en todas las variables. Parece posible una mayor sensibilidad basada en el match-DSL en comparación con el match-jerk. Los jugadores de primera línea y pivotes exhibieron los valores más altos de match-DSL. De forma divergente, los extremos cubrieron más distancia en carrera a alta velocidad mientras mostraban un menor match-DSL en relación con la primera línea. Las variables de locomoción proporcionan ventajas prácticas en comparación con match-DSL y match-jerk. Futuros estudios son necesarios que exploren la validez de las métricas y parámetros establecidos arbitrariamente y comparen estas variables de carga externa con las de carga interna.
Palabras clave: balonmano; jerk; DSL; acelerometría; rendimiento físico.

Introduction

The rule changes reached by the International Handball Federation (IHF, 2016), from the fast throw-off after every goal, to the reduction of allowed passes in passive play and the increase of the throw-off area, mixed with game tactical-strategical changes, have contributed to a faster and more attractive game for players and spectators. Still, the counterpart is most likely a more physically demanding game imposing higher loads on the players. The simple movement patterns and the physical characterization of the game have been challenging, with the first studies using notational analysis (Michalsik & Aagaard, 2015; Michalsik et al., 2013; Michalsik et al., 2014, 2015; Povoas et al., 2014; Povoas et al., 2012), which was time-consuming, observer-dependent, and not-easily reachable in time to coaches and training staff of the teams. Later, optical-based tracking systems (Cardinale et al., 2017) and GPS systems sped up the process of kinematic data collection, processing, and accessibility to the teams' coaching staff. While the optical systems required a complex process for image digitalization and lacked portability, the GPS was limited to outdoor team sports but gained popularity in football and rugby (Torres-Ronda et al., 2022). It was with the emergence of the Local Positioning System (LPS) technology based on the Ultra-Wideband (UWB) signal that indoor tracking became feasible for more accurate measures of players' position in real time (Bastida-Castillo et al., 2019). The tracking systems evolved, and other sensors were integrated, like inertial measurement units (IMUs), allowing the recording of the coordinates and accelerations of the players simultaneously (Scott et al., 2016). Similarly to other team sports, this breakthrough allowed handball researchers to calculate a multitude of kinematic variables based on mainly three types of kinematic motion: displacement, velocity, and acceleration. In displacement, the main metrics studied were distance covered and running pace (Manchado et al., 2020; Manchado et al., 2021). Then, in velocity, maximum speed, average speed, and time spent in certain speed thresholds (Font et al., 2021). Finally, in acceleration, the most studied variables were high-intensity events (HIE), which count the number of accelerations, decelerations, and change-of-directions (Font et al., 2021; Luteberget et al., 2017). Moreover, metrics that mix two types of motion (e.g. displacement and velocity) have also been used, like the distance covered at certain velocity thresholds, where the high-speed running distance is the most used metric (Ezquerra-Condeminas et al., 2024; Pérez-Armendáriz et al., 2024). Lately, researchers have introduced compound metrics based on the rate of change in acceleration, called jerk in classic physics, as a way to quantify the change in the force exerted on the body (Eager et al., 2016). Researchers have highlighted that it is possible to measure muscular movement smoothness with jerk and that its deterioration can be influenced by fatigue, training, and injury history among other factors Kiely et al. (2019). Also, the central nervous system has a key role in motion smoothness and its decline can be seen through a decay in motor coordination and, therefore, a less smooth movement pattern, such as running or lifting something. One of the main advantages of this metric is that it can easily overcome the gravitational acceleration problem present when analysing the acceleration values (Eager et al., 2016; Link et al., 2019).

Although this metric (jerk) seems to be useful for measuring physical and mental fatigue (Eager et al., 2016; Zhang et al., 2019), it is still not quite studied in a training environment in team sports, and it has only been studied for limb fatigue (Hostler et al., 2021; Kiely et al., 2019). Moreover, a very common external load metric in team sports, the Player Load (PL) (Boyd et al., 2011), is based on the jerk. This metric has already been employed in handball as a tool to assess the external mechanical load on players (Carton-Llorente et al., 2023; González-Haro et al., 2020; Font et al., 2021; Luteberget et al., 2018; Luteberget et al., 2017; Wik et al., 2017). However, Bredt et al. (2020) exposed methodological problems associated with the use of this metric, due to multiple interpretations and different implementations, thus publishing similar articles with notably different results.

García-Sánchez et al. (2023), in their systematic review, also discussed this question of inconsistencies, mainly driven by the use of different tracking systems with different algorithms, on the calculation of the PL that led to the impossibility of comparing results between studies on handball.

At present, the choice of the metrics used for measuring the players' physical exertion seems to be subjective, and inconsistent, raising doubts as to what the metrics offer to the coaching staff of the teams. Not only that, the lack of reference and standard values of acceleration-based metrics in handball makes it unrealistic to diagnose and predict fatigue, match overloaded situations, performance decay and eventually injury risk.

Therefore, our objectives are to quantify the external mechanical load during competitive match play using acceleration-based load and locomotive metrics, introduce novel metrics in handball, compare the external load among playing positions, and contribute to improving and promoting better and open-access implementations of metrics, shedding light on their potential utility.

Materials and Methods

Research Context

The data source used in this study was collected under the umbrella of a major project conducted during the 2022 European Men's Under 20 Handball Championship. The research project was carried out by the Faculty of Sports of Porto (FADEUP) and the University of Trás-os-Montes and Alto Douro (UTAD), with the support and collaboration of the European Handball Federation (EHF) and the Portuguese Handball Federation. After getting the formal EHF authorization to equip players with wearable devices, all participating national federations were contacted, informed about the study procedures, and invited to voluntarily participate. After accepting, an individual player's electronic consent (e-consent), elaborated according to the Declaration of Helsinki, was sent to each player, and collected by the team officials. Later, in the preparatory technical meeting with all team representatives, just before the championship started, more detailed information was provided and was underlined that, at any moment of the data collection, any team or player had the opportunity to refuse or cease participation without any consequences.

Instruments and procedures

All match data was collected with a wearable 20-Hz LPS system with 100-Hz embedded accelerometers (WIMU PRO, RealTrack Systems, Almería, Spain). The WIMU Ultrawideband (UWB) system utilized eight antennas positioned around the handball courts at approximately the same height. The system operates by means of triangulations between antennas and is connected to a server.

It is worth noting that the LPS validity studies, in indoor conditions, reported better results than the GPS positional data in outdoor conditions, thus constituting a viable system (Alt et al., 2020; Bastida-Castillo, A., 2018; Fleureau et al., 2020); however, it should be taken with precautions as the position recording accuracy may be affected as the instantaneous velocity of the device increases (Luteberget et al. 2020). An inter-device reliability preliminary study was conducted in the hall where the games were recorded and the median coefficient of variation for the x and y-axis displacement was 4.42% and 4.64 %, respectively, demonstrating a 'good' inter-device agreement (Crang, Z. L. et al., 2022).

On the tournament's first game day eve, the tracking system was installed, calibrated, and tested with the aid of a technician from the system company. This process was repeated on each game day to check whether there were any anomalies in the synchronisation and calibration and whether the devices were fully operational. The players used a chest-worn vest tight to the body with a pocket to insert the tracking device, placed on the upper Backs around the T4-T5 vertebrae.

Due to limited tracking equipment, 27 games were recorded (≈48 % of total competition), resulting in potentially eligible 711 player-match observations from 11 national teams. The number of games recorded per round was: Preliminary Round – 12; Main Round – 4; Intermediate Round – 4; Placement Matches – 3; Final-Four – 4. The players were divided by the 4 positions commonly known: Backs (n = 319), Wings (n = 169), Line Players (n = 116), and Goalkeepers (n = 107). The playing positions were given according to web data extraction from the EHF competition website.

For the overall characterization of the physical exertion, all players were included, irrespective of whether they were on or off the court, and the time stoppages were also considered, except for the half-time break. Nevertheless, most studies only consider the effective playing time by manually excluding the time stoppages (timeouts, ball out of play, injury interruption, etc.) or by automatically removing periods when the player is off court done with the help of an automated algorithm (Bassek et al., 2023). The automatized process has limitations, as sometimes, it would incorrectly flag players on or off the court when they were close to the court limits.

Subsequently, a subset of players in each playing group was constituted by those who achieved the top 25% results (statistical fourth quartile) for each computed variable, was used to compare positions. This approach ensures that the analysis relies on players who exhibited higher levels of physical exertion, thereby aiding in capturing positional disparities that are more representative of competitive match-play. The acceleration-derived metrics measured for the load volume were the match-jerk (equation 1) defined as the sum of the jerk norm, known as the change in acceleration over time (Eager et al., 2016) and its unit of measurement in the reduced form is G. The match Dynamic Stress Load (match-DSL) (equation 2) concept is a metric that has been previously used in soccer (Pino-Ortega et al., 2021) and Rugby (Stevens et al., 2024), but, to the best of our knowledge, it has not yet been applied to Handball. The metric is defined as the sum of the weighted acceleration-based impacts over 2G, where an impact of 4G is more than twice as damaging as an impact of 2G (Gaudino et al., 2015), since the exponent is defined as three, its unit of measurement in its reduced form is $G^3 \cdot s$ ("G cubed seconds"). The acceleration norm vector for the match-DSL was smoothed through a moving average with a 0.1-second window.

For the locomotive metrics, the total distance covered, and the High-Speed Running (HSR) distance were considered. The threshold criteria for HSR in handball has been arbitrary, lacking validation or consensus among researchers, with values ranging from 4 to 5.5 $m.s^{-1}$ (Bassek et al., 2023; Carton-Llorente et al., 2023; Fleureau et al., 2023; Manchado et al., 2020; Manchado et al., 2021; Saal et al., 2023). Nevertheless, we decided to follow the Carton-Llorente et al. (2023) study, whose threshold is defined as 4.4 $m.s^{-1}$.

After each game, the data was collected and exported to a CSV (comma-separated values) file. All the data processing occurred in Python (version 3.11) programming language.

$$match-jerk = \sum_i \left\| \frac{d\vec{a}}{dt} \right\|_i \cdot \Delta t_i \tag{1}$$

$$match-DSL = \sum_i (t_{i+1} - t_i) \cdot IMPACT_i^3, IMPACT_i = \begin{cases} \|\vec{a}_i\|, & \|\vec{a}_i\| > 2\ G \\ 0, & else \end{cases} \tag{2}$$

Statistical analysis

In the first instance, an exploratory analysis was done with the following descriptive statistics: mean, standard deviation, minimum value, maximum value, 25th percentile, 50th percentile (median), and 75th percentile. Extreme outliers were excluded following the interquartile range rule for group comparisons.

A Shapiro-Wilk test was done on every group to detect normality, with a significance level of < .05. Given that all groups were found to have a non-normal distribution, to compare the independent groups, a Kruskal-Wallis H Test was followed by a Dunn's Test for pairwise comparison with a one-step Bonferroni correction. To quantify the effect size, Cohen's d_z was calculated, with the following classification: small (0.10–0.29), medium (0.30–0.49) and large effect (>0.50) (Field, 2017).

Results

Table 1 shows the selected descriptive statistics for each of the four variables analysed considering the overall recorded data and the top 25% (fourth quartile) player-match observation for each computed variable, grouped by attacking positions and goalkeepers.

Table 1. Descriptive statistics for Back, Wing, Line Player, and Goalkeeper**.**

Total		BACKS	GOALKEEPERS	LINE PLAYERS	WINGS
Match-DSL (G^3·s)	Mean ± SD	2423.4 ± 1720.9	613.1 ± 445.4	2192.8 ± 1500.4	2289.2 ± 1586.1
	25%	1137.00	212.0	1383.8	1040.4
	Median	2334.5	578.7	2090.8	2416.5
	75%	3450.6	801.2	2696.5	3251.5
Match-Jerk (G)	Mean ± SD	40394.3 ± 21298.2	22098.7 ± 14050.5	41370.6 ± 15315.0	38074.0 ± 18317.1
	25%	23798.9	14084.3	31285.6	24994.9
	Median	43350.9	20866.3	43202.2	38701.2
	75%	55577.3	27697.8	52531.9	49857.9
Distance Covered (m)	Mean ± SD	3097.6 ± 1340.6	1964.2 ± 758.1	3124.79 ± 1053.6	3281.9 ± 1368.7
	25%	2007.0	1393.5	2523.5	2267.4
	Median	3290.1	1929.8	3140.2	3485.4
	75%	4146.0	2462.1	3854.4	4211.8
HSR Distance (m)	Mean ± SD	316.1 ± 223.2	44.8 ± 58.1	416.03 ± 267.9	698.9 ± 420.2
	25%	149.5	3.6	275.9	408.6
	Median	297.5	29.7	387.5	703.8
	75%	457.2	52.5	487.4	1023.9
Top 25 %		BACKS	GOALKEEPERS	LINE PLAYERS	WINGS
Match-DSL (G^3·s)	Mean ± SD	4352.7 ± 606.7	1222.2 ± 274.7	3542.6 ± 765.6	3931.9 ± 591.0
	Median	4319.2	1241.5	3271.1	3645.3
	IQR	[3883.3, 4719.7]	[989.4, 1394.3]	[2976.4, 3866.9]	[3467.3, 5369.5]
	Max	6130.5	1834.6	5369.5	5379.8
Match-Jerk (G)	Mean ± SD	63680.4 ± 6151.9	34040.3 ± 4143.4	59750.5 ± 5631.2	60353.9 ± 7130.1
	Median	62453.7	34049.5	58097.2	59169.2
	IQR	[59272.4, 67326.5]	[30739.8, 36515.5]	[55311.3, 62429.4]	[54601.9, 65837.5]
	Max	80621.1	42199.8	75233.1	77646.7
Distance Covered (m)	Mean ± SD	4744.5 ± 433.2	2951.8 ± 365.3	4424.4 ± 527.9	4874.3 ± 461.2
	Median	4733.8	2785.6	4254.8	4701.5
	IQR	[4351.6, 5043.5]	[2703.9, 3213.2]	[4136.2, 4521.3]	[4464.5, 5204.8]
	Max	5776.4	3716.5	6020.2	6090.9
HSR Distance (m)	Mean ± SD	615.5 ± 136.2	119.80 ± 71.1	744.9 ± 308.2	1220.5 ± 169.8
	Median	580.9	95.37	605.3	1173.8
	IQR	[514.7, 674.0]	[67.4, 154.7]	[541.2, 789.4]	[1090.9, 1321.3]
	Max	1199.1	341.8	1636.9	1690.2

To visualize the distribution (median, lower, and upper quartiles, and lower and upper extremes data) of each selected external load variable by playing position, a series of box and whisker plots were built and are presented in Figure 1. The effect size, when significant differences occur, will be represented as the following: small (*), medium (**), and large (***).

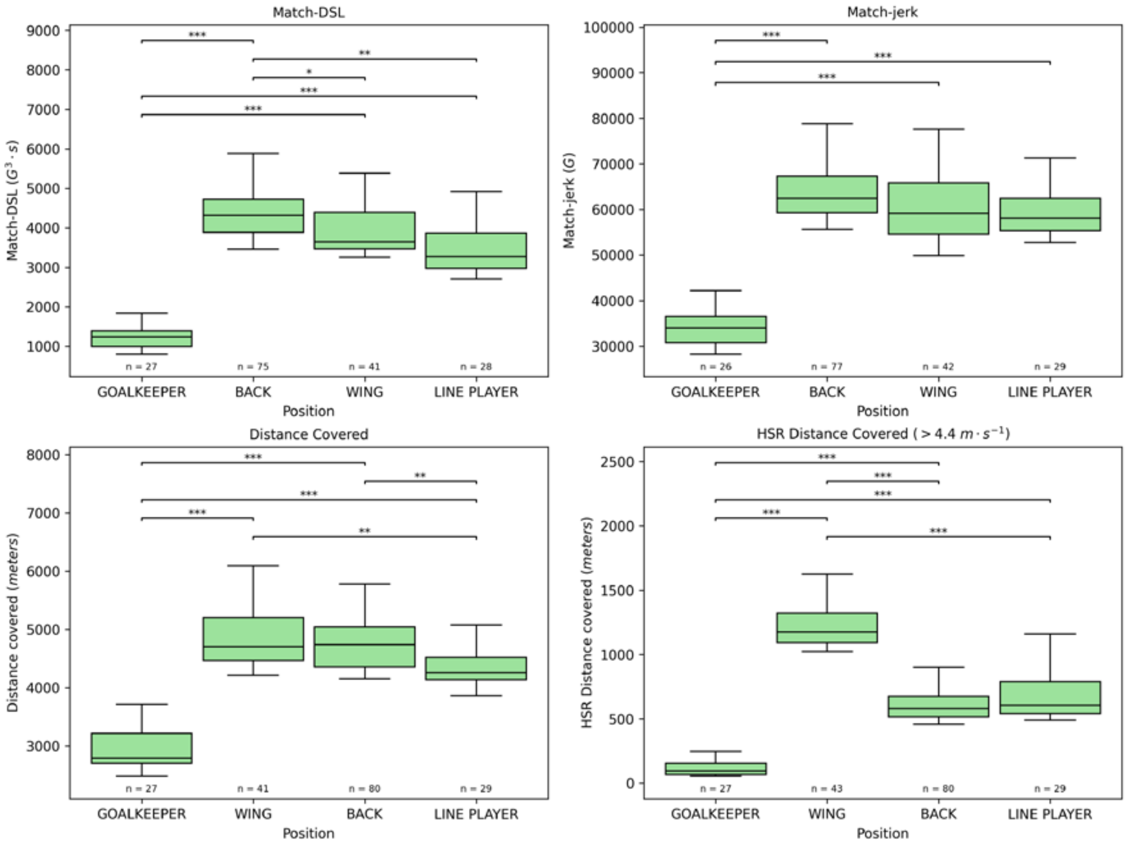

Figure 1. Distribution boxplots and pairwise comparisons with Cohen's d_z effect size. between the top 25 % (4th Quartile) of each position for all metrics analysed. *, **, *** represent respectively small, medium, and large size effects.

Regarding the match-DSL values, significant differences were found across the four playing position groups (H (3) = 89.966, p-value = < .001), whereas the Goalkeepers showed significantly lower values than the Backs (p-value < .001, d_z = -0.91), the Wings (p-value < .001, d_z = -0.76), and the Line Players (p-value < 0.001, d_z = -0.54). Also, the Backs were found to be significantly higher than the Wings (p-value < .001, d_z = 0.25). However, there was no significant difference between the match-DSL of Wings and Line Players (p-value = .336, d_z = 0.23).

For the match-jerk, significant differences were found among the four positions (H (3) = 74.780, p-value = < .001). Subsequent *post hoc* analysis revealed that the Goalkeepers had significantly lower match-jerk than that of the Backs (p-value < .001, d_z = -0.85), the Line Players (p-value < .001, d_z = -0.71), and the Wings (p-value < .001, d_z = -0.74). However, there were no significant differences found between the pairs of the three field positions.

For the distance covered, significant differences were also found (H (3) = 82.825, p-value = < .001). The *post hoc* revealed that the Goalkeepers had a significantly lower distance covered than that of the Backs (p-value < .001, d_z = -0.78), the Line Players (p-value < .001, d_z = -0.56), and the Wings (p-value < .001, d_z = -0.99). Also, the Wings had significantly higher results than the Line Players (p-value = .001, d_z = 0.44). Finally, the Backs were significantly higher than the Line Players (p = 0.01, d_z = 0.30). No differences were observed between the Backs and the Wings (p-value = 1.000, d_z = 0.10).

Regarding the HSR distance covered by playing position, Significant differences were also found (*H* (3) = 127.07, p-value = < .001). Subsequent tests indicated that the HSR distance of the Wings was significantly higher than that of the Goalkeepers (p-value < .001, d_z = 1.31), Line Players (p-value < .001, d_z = 0.56), and the Backs (p-value < .001, d_z = 0.69). Also, the Goalkeepers showed significantly lower values than the Line Players (p-value < .001, d_z = 0.78) and the Backs (p-value < .001, d_z = 0.55). However, there was no significant difference between the HSR distance covered by the Line Players and Backs (p-value = 0.952, d_z = 0.14).

Discussion

This is the first study, to our knowledge, to investigate differences in the physical activity profiles of playing positions in an elite youth male handball competition. The main findings were a) the Goalkeepers were consistently the position with lower values in every metric; b) the Wings stood out in the locomotive metrics (distance covered and HSR distance); c) the match-DSL found significant differences between positions whilst the match-jerk did not, with the Backs standing out at the top, followed by the Wings and the Line Players, successively. In addition, the introduction of novel metrics for assessing mechanical load adds another layer of depth, enabling a more comprehensive calculation of load.

Most commonly, researchers assess kinematic external load metrics with the help of companies' software, being frequently blind about the algorithms and filtration process used, hindering the comprehension of the methodologies used and the transparency of the results (Bullock et al., 2022; Garcia-Sanchez et al., 2023; Malone et al., 2017). Here, the data processing was done by exporting raw data and computing the metrics independently through Python, intending to bring a transparent implementation of already used metrics and novel metrics in the handball scope, like the match-DSL. Therefore, due to methodologic differences in previous studies metrics and data processing, direct comparisons of accelerometer-based player load results with other studies are difficult or even unfeasible.

Also, divergences regarding the playing positions used limit comparison between physical activity profiles among studies. Some authors divide the court positions into three groups: Backs, Wings and Line Players (Bassek et al., 2023; Luteberget et al., 2018; Luteberget et al., 2017; Wik et al., 2017), while others opt to analyse in four groups: Centre Backs, Backs, Wings, and Line Players (Carton-Llorente et al., 2023; Font et al., 2021), or even in the six court positions (Manchado et al., 2021; Manchado et al., 2020). From our perspective, there is no functional reason to separate the centre from left and right-back players, and the same occurs with the wings. Therefore, this study used four playing position groups (Backs, Wings, Line Players, and Goalkeepers).

Locomotive metrics

The Wings and Backs were the top two positions regarding the total distance covered, followed by the Line Players and, lastly, by the Goalkeepers. The results align with expectations, as the specific Wings position gives players more space to run up and down the court, and the Backs are usually involved in more offensive breaking-through attempts, combined with defensive responsibilities carried out in the core of the defensive system. The Goalkeepers consistently exhibited lower values of mechanical load in both metrics (distance covered and HSR distance), presenting significant differences of large magnitudes compared to other positions. These findings were not unexpected, as the Goalkeepers role typically entails less kinematical load from locomotive actions, as reported in previous studies (Luteberget et al., 2018; Luteberget et al., 2017). Additionally, Goalkeepers are often excluded from the kinematic analysis for this reason (Bassek et al., 2023; Cardinale et al., 2017).

The results show that the Wings ran substantially higher distances at high speed than all other positions with medium and large magnitude differences compared to the Line Players, and Backs respectively, similar to other studies' findings (Bassek et al., 2023; Carton-Llorente et al., 2023; Saal et al., 2023). For Wings, the results were expected, as these players have more court length available and are the ones that usually have the tactical role of a fast-breaking way, forming the first *wave* (or line) of the fast break to get an open scoring opportunity (Póvoas et al., 2014). Surprisingly, the

Line Players ran similar HSR distances to the Backs. One possible reason might be a similar tactical role to the Wings, where, usually, coaches instruct the Line Players to join the first *wave* of the fast break together with the Wings, leaving the last *wave* for the Backs; another possible reason is the usage of assigned Line Players mainly for defensive tasks, a situation that demands quick runs from and towards the substitution area.

Acceleration-based metrics

Regarding the match-DSL pairwise comparisons, the Backs are at the top with significant differences compared to Wings, Line Players, and Goalkeepers. However, the effect sizes varied in magnitude. The Wings displayed a small effect size, indicating substantial but minimal differences compared to the Backs. The Line Players exhibited a medium effect size, indicating a more pronounced difference. The Goalkeepers showed a large effect size, highlighting an evident and expected distinction compared to the Backs. Moreover, the Goalkeepers also presented substantially lower results, with moderate magnitude, compared to the Wings and Line players confirming the results from the locomotive metrics. Surprisingly, the Wings and Line Players have similar results in this metric.

In terms of the match-jerk results, it was observed that the Goalkeepers consistently experienced substantially lower loads compared to the other positions, a finding already evidenced by the match-DSL and by the locomotive metrics. Still, no differences were found between Backs, Wings and Line Players, a trend consistent with previous studies, such as those by Font et al., (2021) and Carton-Llorente et al., (2023) studies. The relationship between distance covered and acceleration-based variables has been previously studied, with a very high correlation coefficient found between them (Heishman et al., 2020). This can explain the similarities between the Wings and Backs in both distance covered and match-jerk, so the match-jerk might be an alternative to the distance covered.

Looking at the match-DSL and its potential contribution allows for certain assumptions to be drawn. The concept behind the match-DSL resolves around the introduction of an exponent (=3), considering that impacts absorbed by the body become exponentially more dangerous as their magnitude increases (Gaudino et al., 2015). This notion of exponential impact is not novel, with the heart-rate-based training impulse having a similar pattern related to lactate production (Banister & Calvert, 1980). This nuance, compared to the match-jerk, can unlock hidden patterns seen by the significant differences that appeared between the Backs and the other two field positions, where the Backs are exposed to high-intensity actions of greater magnitudes during the game.

Additionally, the threshold of 2G might be a good solution to exclude trivial moments like timeouts or even those long portions of time when the players are simply walking or jogging which might overestimate the results. The match-DSL simply excludes impacts or accelerations of lower intensities during those periods and, if impacts higher than 2G happen, then it will be included in the data, regardless of the state of the game. Moreover, it can be thought of as an evolution to the high-intensity events variable, where the magnitude of those events is valued instead of a simple count. Nonetheless, the exponent as well as the threshold still need to be thoroughly validated based on internal load markers and applied accordingly to the target population. For example, in untrained populations, the threshold of 2G might be too high to detect damaging impacts, or the exponent might be too low to represent the due effect on the body, thus masking impacts that can be potential hazards, for example, young non-elite athletes with lower tolerance limits (Matthys et al., 2013; Mónaco et al., 2019).

The match-jerk, on the contrary, is sensitive to noise due to missing an intensity threshold which means, every time a player moves or tilts his body, it counts as data, thus producing very high results. It is worth mentioning that the match-jerk can be analogous to the Player Load measurement and calculus, analysed by Font et al. (2021) and Wik et al. (2017). However, a direct comparison of results cannot be made due to distinct algorithms driven by the usage of different tracking systems. When calculating as equation 1, the unit of measurement of match-jerk is G in its reduced (summated) form, contrary to other studies where it is reported in arbitrary units (Font et al., 2021; Wik et al. 2017).

The essence of the locomotive and acceleration-based metrics, like the ones in this study, requires movement to capture physical exertion very intense and abrupt actions, like jumps, landings, change-of-directions, and collisions, can be measured. Still, the lack of capability of capturing the isometric load underestimates the mechanical load measurement of the Line Players greatly, where most of the load occurs when trying to gain positional advantage with “static” screens (Font et al., 2021).

Some limitations were found in this study. The tight schedule between games, particularly in certain rounds with up to four consecutive matches within a span of 10 hours, coupled with the limited availability of devices and their restricted battery capacity, results in some games being discarded. Moreover, in some instances, players may conclude the game with fully discharged devices, leading to their exclusion from the data. Furthermore, even though the metrics used in this study are accessible through the commercial device system, the lack of transparency regarding the calculation (filters and parameters) of the DSL add~~ed~~ a layer of processing complexity. As a result, the metrics were computed through a Python custom script instead of the device’s system software. Finally, in this study, the definition of the playing position was based on the available information on the EHF competition website, so it is not possible to account for possible position changes within games or between games during the competition.

Conclusions

This study identified differences in the physical activity among playing positions, confirming its specificity. The Backs were found to experience a higher match-DSL load, indicating an increased exposure to high-magnitude actions and impacts, followed by the Wings, Line Players, and, finally, Goalkeepers. In the match-jerk, differences were observed solely between the Goalkeepers and the field positions.

The match-DSL was revealed to be a promising tool to assess the mechanical external load, although there are some caveats to consider. This metric provides enhanced capability in quantifying and valuing higher impact magnitudes, thereby distinguishing positions characterized by numerous high-impact events, such as the Backs, from those with many but lower-impact events, such, as the Wings and Line Players. The match-jerk remains a potentially useful metric for capturing the volume of the impacts, providing a broader perspective, but further research is still needed. Both of these metrics still have limitations in capturing quasi-isometric mechanical loads, which are particularly evident in the case of the Line Player, due to the device’s inability to effectively capture exertion data from actions that require high muscle strength during body contact but are slow or almost static.

The locomotive variables (distance covered, HSR distance covered) displayed that the Wings are the ones that run the most in total and at high speed, propelled by the possible tactical roles in fast-break and the extra space to run in the outer corridor of the court, followed by Backs, Line Players, and Goalkeepers. Although the Backs were significantly higher than the Line Players in the distance covered, that was not the case in the HSR distance, contradicting other studies.

For future research, we suggest analysing the physical activity by game phase and the effective positioning on the court. Hence, it would be possible to assess the positional load more accurately. Moreover, the novel metric match-DSL introduced in this study, is encouraged in other populations (female players, senior players, non-elite players, etc.).

Practical implications

The match-DSL has emerged as a promising tool for monitoring external mechanical loads and capturing the load patterns according to game positions' specificity that the match-jerk does not capture. By valuing impacts at higher G, the match-DSL metric seems helpful in a better understanding of mechanical intensity in handball and having the significant advantage of needing only an accelerometer attached to the player's back, sparing the installation of LPS infrastructure in the pavilion for positional data tracking. The match-DSL captures the most intense actions whilst discarding uninteresting moments from a physical demand point of view without the need for extensive data cleansing efforts.

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