MONITORING EXTERNAL LOAD DURING REAL COMPETITION IN MALE HANDBALL PLAYERS THROUGH BIG DATA ANALYTICS: DIFFERENCES BY PLAYING POSITIONS

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Abstract:

The present study aimed to analyze the external load put on elite male handball players during the 2020 European Championship differentiated by playing positions. A system based on three phases was designed: 1) information capture of game events through sensor networks, LPS system and WebScraping techniques; 2) information processing based on Big Data Analytics; 3) extraction of results based on a descriptive analytics approach. Results showed that wings (Ws) and center backs (CBs) performed more accelerations and decelerations than the players in other positions in the entire match and attack. In defense, wings showed higher values than the rest of the players, followed by line players (LPs). In regard to body contacts, the positions that received more average number during the whole match were the CBs and LPs, with the CBs presenting the highest values in offense and the LPs in defense. Finally, backs were the ones performing more total jumps per game and in offense. In defense, LPs and left backs presented the highest values. It is necessary to monitor individual high intensity events to develop individual training programmes for different playing positions. High-intensity decelerations should be specially considered since they enlarge injury risks.

Keywords: *accelerations, decelerations, body contacts, jumps, performance analysis*

Introduction

Workload quantification is defined as the process of recording training and competition workload demands to regulate training volumes and intensities in athletes and to decrease the risk of injuries and overtraining (Bourdon, et al., 2017). Handball is a team sport that requires intermittent high-intensity actions such as accelerations, decelerations, body contacts, high-speed displacements, and jumps (Karcher & Buchheit, 2014). To be accurate, these demands should be assessed individually as each player will respond differently to the same training and competition workloads (Gómez-Carmona, Bastida-Castillo, Ibáñez, & Pino-Ortega, 2020).

The possibility of knowing and being able to monitor these high-intensity actions in real matches is the key to optimizing the training process (Font, et al., 2022), improving player's performance (Font, et al., 2021), and reducing injuries (Harper, Carling, & Kiely, 2019; Luig, et al., 2018). Coaches can now individualize players' workloads according to game demands (Barbero, Granda-Vera, Calleja-González, & Del Coso, 2014), since playing positions largely influence game demands (Manchado, Pueo, Chirosa-Rios, & Tortosa-Martínez, 2021) and may be related to metabolic power parameters (Venzke, Schäfer, Niederer, Manchado, & Platen, 2023). Furthermore, coaches could use this specific information to prepare players for the worst-case scenario, which is the highest possible demand within brief time intervals (Carton-Llorente, Lozano, Iglesias, Jorquera, & Manchado, 2023).

The way of approaching the study of external load in competition has been changing in parallel with technological advances. From the use of the video camera with manual digitization (Alexander & Boreskie, 1989) to portable microtechnology of local positioning (LPS) (Font, et al., 2021; González-Haro, et al., 2020), going through automatic tracking systems by video cameras (Manchado, Tortosa-Martínez, Vila, Ferragut, & Platen, 2013).

With the recent appearance of Sensor Networks and LPS technological development, applicable to indoor sports, a quality leap has been made in load control in indoor sports (Gómez-Carmona, et al., 2020; Kniubaite, Skarbalius, Clemente & Conte, 2019). Due to its small size and easy placement, it has allowed for studying new variables, such as jumps, shots, accelerations, etc., giving useful information and allowing to generate new analysis indexes for researchers and coaches (González-Haro, et al., 2020).

Despite the importance and growth in the number of researches and technological improvements cited, scientific knowledge about handball competition's demands is still insufficient. Previous studies have provided very limited specific information based on game-simulated situations in elite women (Luteberget & Spencer, 2017; Wik, Luteberget, & Spencer, 2017), training sessions in young players (Ortega-Becerra, Belloso-Vergara, & Pareja-Blanco, 2020), an amateur team (González-Haro, et al., 2020), or one single elite team during a season (Font, et al., 2021; Kniubaite, et al., 2019).

Thus, this study aimed to analyze position-specific physical demands elite handball players should meet in offense and defense by measuring external load during European Championship matches. These profiles can provide a benchmark for coaches to optimize individual player preparation based on the activities they perform during a major championship. To make this study feasible, it has been necessary to capture a huge amount of data from heterogeneous sources, process them to obtain value-added information and analyze them to draw conclusions that provide knowledge and can help in decision making. To this end, a specific methodology has been proposed based on sensor network technologies and Local Positioning System (LPS), Big Data Analytics, and a descriptive analytics approach.

Materials and methods

In this study, a descriptive observational cross-sectional study was used to examine external load according to playing positions and phases of the game during competitive matches. Playing phases (offense/defense) were distinguished based on ball possession and overall player movement. Ball possession was determined in an automated process in which the sensor of the ball and the sensors of the player had to move in the direction of the opponent's goal. To be considered as an offensive phase the ball must go forward in a stable possession for at least three meters and the respective team must keep the ball possession for two seconds (Venzke, et al., 2023).

Data were obtained from all the players participating in the European Handball Federation (EHF) Men's EURO 2020. This study is part of a larger study analyzing different aspects of competition physical demands in elite handball, with several studies published previously (Manchado, et al., 2021; Pueo, Tortosa-Martínez, Chirosa-Rios, & Manchado, 2022; Pueo, Tortosa-Martínez, Chirosa-Rios, & Manchado, 2023). None of these previous studies focused on high intensity activities such as accelerations, decelerations, body contacts and jumps.

In order to analyze the external load of the players, an integral system based on Sensors Network, LPS (Kinexon Precision Technologies, Munich, Germany) and Big Data Analytics (Bai & Bai, 2021; Gil, Johnsson, Mora, & Szymański, 2019) was designed. Each device, a sensor (player tag) whose dimensions were 49x33x8 millimeters (height/width/depth) and weighed 14 grams, was fitted to the back of each player with an adjustable vest. LPS Kinexon units can measure the fundamental handball movement demands in terms of peak speed, peak acceleration, and peak deceleration (Fleureau, Lacome, Buchheit, Couturier, & Rabita, 2020).

For this study, 485,806,812 records were analyzed regarding accelerations, decelerations, body contacts and jumps. Kinexon system has been validated against well-known systems such as GPS, showing proper between-device reliability (coefficient of variation around 5%) (Blauberger, Marzilger, & Lames, 2021; Fleureau, et al., 2020; Hoppe, Baumgart, Polglaze, & Freiwald, 2018).

Subjects

Data were obtained from 357 male players from 24 national teams in 65 matches, participating in the European Handball Federation (EHF) Men's EURO 2020, held in Austria/Norway/Sweden. The players were distributed in the following playing positions: left wing (LW), left back (LB), center back (CB), right back (RB), right wing (RW) and line players (LP). The goalkeepers were excluded from the study because their workload demands and technical-tactical actions differ from those of court players (Wagner, Finkenzeller, Würth, & Von Duvillard, 2014). Anthropometric characteristics and the age of the players are presented in Table 1. This information was collected from the official statistical data provided by the EHF.

The study was approved by the EHF. The players were informed of the purposes, procedures, and risks of the study and provided informed consent before the beginning of the study in a contract with the EHF. Personal data were anonymized for this study. All the procedures were conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013) and approved by the Ethics Committee of the University of Alicante (registration number UA-2020-09-10).

Table 1. Physical characteristics of the players (mean ± standard deviation)

Playing position	N	Height (cm)	Body mass (kg)	BMI (kg/m²)	Age (years)
Left wing	48	186.9±5.7	84.4±7.9	24.2	28.3±4.6
Left back	73	196.1±4.2	97.2±6.5	25.3	26.8±4.7
Centre back	55	189.7±5.8	90.3±6.9	25.1	27.5±5.0
Right back	52	194.4±5.8	95.7±8.9	25.3	27.9±4.8
Right wing	50	184.6±5.4	83.1±6.3	24.4	28.0±4.4
Line player	79	196.8±4.6	105.3±8.5	27.2	28.5±4.7
Total	357	192.2±6.9	94.1±10.9	25.4	27.8±4.7

Note. BMI=body mass index.

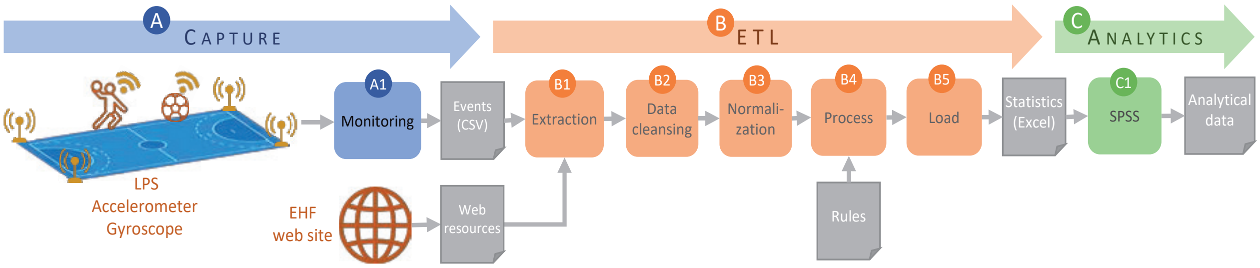


Figure 1. Modular system for data capturing, processing, and analysis.

Procedures

To carry out this study and guarantee its viability, an integral system based on Sensors Network, LPS and Big Data Analytics (Bai & Bai, 2021; Gil, et al., 2019) was designed, oriented to the characteristics and needs of handball. A large amount of information to be processed and the heterogeneity of data sources and formats made it necessary to propose a system that automated this process to obtain the information in a limited time and with adequate quality. As a result, a modular system that allowed the implementation of the proposed methodology with the objective of capturing, storing, processing, and analyzing the information necessary for this study was created (Figure 1).

The acquisition module (Figure 1 – A) was responsible for automatic acquisition of the data required for the study. On the one hand, the data was provided by the company Kinexon, through a Sensors Network system that recorded variables related to the events taking place during the matches. A LPS system, to determine the real-time position and motion data, was used to collect the positional data of players and the ball (Blauberger, et al., 2021; Luteberget & Spencer, 2017). A complete description of the system can be found elsewhere (Manchado, et al., 2020, 2021). In both cases, the sensor calculates 3D data (x, y, z) with position accuracy <10 centimeters at a sampling frequency of 20 hertz for players and 50 hertz for the ball. Additionally, the devices are capable of measuring accelerometry and orientation in all three axes.

From these data, a set of specific handball high intensity events (HIE) were identified (Figure 1 – A1): player accelerations (over 2 m/s^2), decelerations (under -2 m/s^2), body contacts (over 3G), and jumps. These HIE were divided into different categories for posterior analysis (Table 2). For the study, these data were obtained under the batch processing model and extracted from a semi-structured format based on a CSV format.

In the extract, transform and load (ETL) phase, the integration and calculation of the value-added data were carried out (Figure 1 – B). First, the multi-sources data were obtained and parsed by developing specific connectors (Figure 1 – B1). Subsequently, the data cleansing process (Figure 1 – B2) was carried out, where wrong or unnecessary records were eliminated, and incorrect, non-existent or inconsistent data were corrected or completed.

In a subsequent process, normalization and transformation of the data were carried out (Figure 1 – B3). Additionally, some variables were calculated on the fly from other records (e.g., duration and timestamps by the phases of the match). Next, the process of aggregation and integration was carried out (Figure 1 – B4). The calculation of the statistical data was parameterized using a set of declarative rules and considering offensive and defensive events. The following variables and categories (Table 2) were considered (total and per minute).

Finally, in the loading process (Figure 1 – B5), all the information was transformed into Excel format files, compatible with the Statistical Package for Social Sciences (SPSS V22.0 for Windows, SPSS Inc, Chicago, USA) software to perform statistical analysis.

Table 2. Variables and categories considered in the study

	HIA (m/s²)	HID (m/s²)	HIBD (G)	HIJ (cm)
Category 1	2-3	-2-3	3-5	<20
Category 2	3-4	-3-4	5-8	20-40
Category 3	>4	>-4	>8	>40

Note. HIA=high intensity accelerations; HID=high intensity decelerations; HII=high intensity body contacts; HIJ=high intensity jumps.

Statistical analyses

Descriptive analysis was presented as means and standard deviations. Data were analyzed for normality using the Kolmogorov-Smirnov test and for homogeneity of variances with the Levene test.

The differences between the different playing positions in regards to the average and the maximum number of accelerations, decelerations, body contacts, and jumps per game were determined by one-way analysis of variance (ANOVA) with the Brown-Forsythe correction, followed by the Games-Howell *post-hoc* testing, appropriate when there is a lack of homogeneity of variances. The effect size of the ANOVA was calculated with omega squared (ω^2), where <0.06 was a small effect, >0.06<0.14 was a medium effect, and >0.14 was a large effect (Field, 2013).

To determine the magnitude of the paired relationships resulting from the *post-hoc*, Cohen's effect size (ES) was used with a modified classification (trivial <0.2, small 0.21–0.6, moderate 0.61–1.2, large 1.21–1.99, and very large >2.0) proposed for sports sciences (Hopkins, 2002) and used in other similar handball studies (Cardinale, Whiteley, Ahmed, & Popovic, 2017; Manchado, et al., 2020). The alpha level of significance was set at $p<.05$.

Results

Table 3 shows the mean number of the total and maximum accelerations, decelerations, body contacts, and jumps per game according to the different playing positions. These values are

Table 3. Mean, standard deviation, and statistical differences in external load variables (total and maximal values) according to specific playing positions

	LW (2)	LB (3)	CB (4)	RB (5)	RW (6)	LP (7)	F(p)	ES
AccT	56.03±28.10^{3457}	34.85±18.43^{4}	43.90±20.98^{57}	36.75±16.96	51.50±29.91^{3457}	33.90±17.85	42.38 (<.001)	0.12
AccTMax	4.38±0.38^{3457}	3.85±0.49	3.95±0.41^{7}	3.85±0.38	4.39±0.38^{3457}	3.77±0.42	110.53 (<.001)	0.24
AccOff	35.38±18.64^{357}	23.34±15.76^{7}	35.54±18.54^{357}	27.14±14.02^{7}	32.20±18.82^{357}	18.19±11.35	51.72 (<.001)	0.14
AccOffMax	4.18±0.49^{3457}	3.64±0.67^{7}	3.87±0.46^{7}	3.75±0.48^{7}	4.11±0.38^{3457}	3.45±0.68	74.39 (<.001)	0.17
AccDef	21.21±10.89^{3457}	12.61±8.93	9.50±6.63	10.44±6.89	20.56±11.52^{3457}	17.53±11.82^{345}	64.30 (<.001)	0.17
AccDefMax	4.15±0.57^{3457}	3.35±0.63	3.21±0.71	3.24±0.62	4.22±0.63^{3457}	3.44±0.64^{45}	117.45 (<.001)	0.27
DecT	34.46±17.98^{357}	28.36±15.60	38.87±19.44^{357}	29.55±15.02^{7}	32.01±20.08^{7}	26.00±13.79	20.17 (<.001)	0.06
DecTMax	-4.10±0.53^{357}	-3.69±0.57	-3.98±0.55^{57}	-3.78±0.53^{7}	-4.11±0.66^{357}	-3.55±0.49	47.15 (<.001)	0.13
DecOff	20.78±12.57^{7}	18.55±11.43^{7}	28.72±15.313^{23567}	19.91±10.59	19.68±13.25	14.41±8.33	41.73 (<.001)	0.12
DecOffMax	-3.97±0.56^{357}	3.56±0.61^{7}	-3.86±0.55^{357}	-3.65±0.53^{7}	-3.95±0.71^{357}	-3.36±0.54	48.13 (<.001)	0.13
DecDef	14.01±7.29^{3457}	10.21±6.48	10.40±5.69	9.88±6.22	12.88±8.20^{345}	11.76±6.52^{35}	13.69 (<.001)	0.04
DecDefMax	-3.68±0.65^{3457}	-3.23±0.62	-3.47±0.65^{37}	-3.31±0.67	-3.70±0.69^{3457}	-3.30±0.55	25.36 (<.001)	0.07
BodycontactT	9.86±8.09	15.73±10.02^{26}	20.14±11.99^{2356}	16.52±9.27	7.59±5.32	18.07±10.72^{236}	60.85 (<.001)	0.15
BodycontactTMax	9.01±3.21	9.94±3.05^{6}	10.81±3.97^{6}	10.10±3.50^{6}	8.16±3.14	9.73±3.28	3.76 (.002)	0.05
BodycontactOff	4.23±4.30	8.37±6.66^{26}	15.53±10.03^{23567}	10.80±6.93^{2367}	3.90±3.49	8.98±7.30^{26}	92.99 (<.001)	0.21
BodycontactOffMax	8.04±3.12	9.08±3.30	10.38±4.04^{26}	9.49±3.71^{6}	7.37±3.09	8.59±3.31	4.88 (<.001)	0.06
BodycontactDef	5.63±5.31^{6}	7.35±6.88^{2456}	4.60±5.16	5.72±4.79^{6}	3.69±3.04	9.08±7.10^{23456}	36.00 (<.001)	0.09
BodycontactDefMax	7.22±3.03	7.48±2.93	6.64±2.89	7.74±2.77	7.11±2.77	7.84±2.84	1.37 (.34)	0.02
JumpT	6.68±4.89	10.85±7.32^{267}	11.36±7.74^{267}	12.09±7.65^{267}	5.75±3.98	7.17±4.79	46.11 (<.001)	0.13
JumpTMax	0.48±0.11	0.62±0.10^{267}	0.63±0.11^{267}	0.63±0.11^{267}	0.53±0.12^{7}	0.42±0.13	34.01 (<.001)	0.34
JumpOff	4.62±3.37^{7}	8.37±5.70^{267}	9.61±6.83^{267}	10.43±6.77^{2367}	4.85±3.26^{7}	3.21±2.43	84.23 (<.001)	0.23
JumpOffMax	0.46±0.12	0.61±0.11	0.62±0.11	0.64±0.12	0.50±0.13	0.38±0.14	37.12 (<.001)	0.37
JumpDef	2.89±2.41^{6}	4.32±4.50^{2456}	2.98±3.07^{6}	2.70±1.97^{6}	1.99±1.22	5.30±3.77^{2456}	28.16 (<.001)	0.11
JumpDefMax	0.40±0.11	0.41±0.12	0.37±0.15	0.37±0.11	0.38±0.13	0.39±0.12	0.69 (.625)	0.001

Note. AccT=total accelerations; AccTMax=maximum total acceleration; AccOff=Accelerations in offense; AccOffMax=maximm acceleration in offense; AccDef=accelerations in defense; AccDefMax=maximum acceleration in defense; DecT=total decelerations; DecTMax=maximum total deceleration; DecOff=decelerations in offense; DecOffMax=maximum deceleration in offense; DecDef=decelerations in defense; DecDefMax=maximum deceleration in defense; ImpctT=total body contacts; ImpctTMax=maximum total body contact; ImpctOff=body contacts in offense; ImpctOffMax=Maximum body contacts in offense; ImpctDef=body contacts in defense; ImpctDefMax=maximum body contacts in defense; JumpT=total jumps; JumpTMax=maximum total jump; JumpOff=jumps in offense; JumpOffMax=maximum jump in offense; JumpDef=jumps in defense; JumpDefMax=maximum jump in defense.

Table 4. Mean, standard deviation, and statistical differences in external load variables normalized per playing time according to specific playing positions

	LW 2	LB 3	CB 4	RB 5	RW 6	LP 7	F(p)	ES
Acc (min)	1.68±0.45^{7}	1.45±2.92	1.61±0.58^{7}	1.81±3.99	1.71±1.66^{7}	1.19±0.36	3.31(.006)	0.01
AccOff	1.07±0.32^{7}	1.04±2.84^{7}	1.33±0.60^{2367}	1.38±3.25^{2367}	1.09±0.90^{7}	0.69±0.40	12.20(<.001)	0.03
AccDef	0.63±0.22^{347}	0.45±0.30^{4}	0.32±0.18	0.47±0.90	0.66±0.80^{347}	0.56±0.27^{34}	12.32(<.001)	0.04
Dec (min)	1.05±0.32^{7}	1.14±0.68	1.41±0.56^{267}	1.36±2.25^{7}	1.05±0.84	0.92±0.32	6.80(<.001)	0.02
DecOff	0.63±0.24^{7}	0.77±1.42^{7}	1.05±0.44^{2367}	0.96±1.81^{67}	0.64±0.42^{7}	0.51±0.24	12.20(<.001)	0.03
DecDef	0.43±0.17	0.38±0.32	0.37±0.20	0.41±0.48	0.42±0.47	0.41±0.16	1.20(.30)	0.004
Bodycontact (min)	0.30±0.21	0.62±0.66^{26}	0.71±0.32^{267}	0.74±1.37^{26}	0.26±0.37	0.63±0.30^{26}	21.20(<.001)	0.06
BodycontactOff	0.13±0.12	0.35±0.60^{26}	0.55±0.28^{2367}	0.49±1.00^{2367}	0.13±0.17	0.33±0.25^{26}	26.28(<.001)	0.07
BodycontactDef	0.17±0.16	0.27±0.32^{246}	0.16±0.17	0.25±0.47^{6}	0.13±0.23	0.30±0.20^{246}	15.59(<.001)	0.04
Jumps (min)	0.20±0.13	0.41±0.45^{267}	0.39±0.21^{267}	0.54±1.29^{267}	0.21±0.48	0.23±0.13	12.27(<.001)	0.04
JumpsOff	0.14±0.09^{7}	0.34±0.47^{267}	0.34±0.20^{267}	0.47±1.14^{267}	0.17±0.43	0.11±0.08	16.37(<.001)	0.05
JumpsDef	0.08±0.07	0.14±0.11^{246}	0.09±0.08	0.10±0.19	0.07±0.09	0.17±0.11^{2456}	19.08(<.001)	0.08

Note. Acc=total accelerations per minute; AccOff=accelerations in offense per minute; AccDef=accelerations in defense per minute; Dec (min)= total decelerations per minute; DecOff=decelerations in offense per minute; DecDef=decelerations in defense per minute; Impcts=total body contacts per minute; ImpctOff=body contacts in offense per minute; ImpctDef=body contacts in defense per minute; Jumps=total jumps per minute; JumpOff=jumps in offense per minute; JumpDef=jumps in defense per minute.

presented for the total game, as well as segmented by offense and defense. Table 4 shows the mean number of these same events according to the minutes played by each player. Both tables also present the results of the one-way ANOVA, showing the statistical differences between the different playing positions, and the effect size of the ANOVA. The effect sizes of the paired differences are represented in Figure 2. In supplementary files, the mean values for the different categories established for each high-intensity event analyzed can be found.

Accelerations

Wings showed the highest total number of accelerations per game showing moderate effect sizes (*d*=0.8–1.0) when compared to RBs, LBs and LPs, and a small effect size with CBs (LW, *d*=0.5; RW=0.2), who presented the second highest values considering the entire game. In the offensive phase, CBs and wings were the positions with more activity, while in the defensive phase, LPs were the ones showing the second highest values after the wings. The highest differences were found between the LWs and the CBs in defense (55% lower; *d*=1.3), and between the LWs and the LPs in offense (48% lower; *d*=1.2). Similar results were found when analyzing separately the three categories of accelerations established but with higher effect sizes found in the differences between the wings and the rest of the players in category 2 (entire game, *d*=1.0-1.5; offense, *d*=0.7-1.5; defense, *d*=0.7-1.6) and category 3 (entire game, *d*=1.3-1.6; offense, *d*=0.8-1.3; defense, *d*=1.3-1.4).

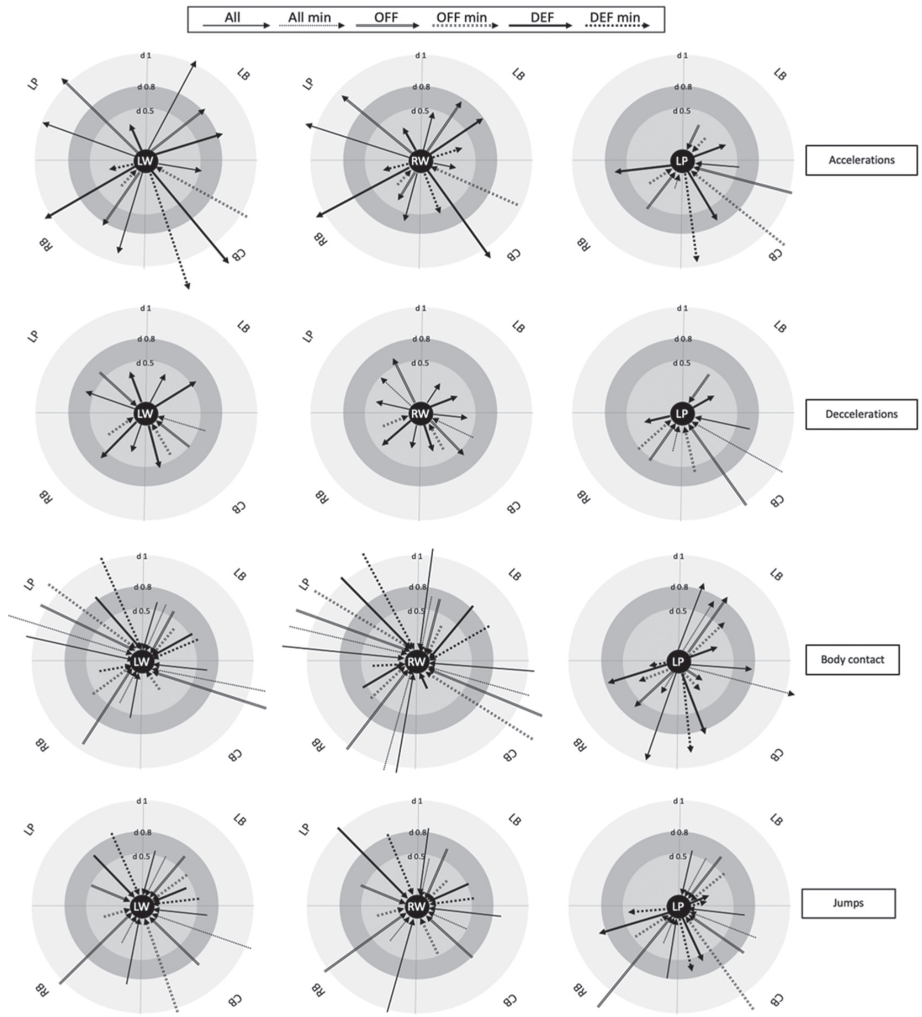
When data were normalized per minutes played, wings showed similar total values to the rest of the players for the entire game other than LPs, who presented the lowest values (30% lower than wings). In offense, CBs and RBs were the ones presenting higher values, while wings showed the highest values in defense. However, when analyzing these differences by categories, wings showed again the highest number of accelerations compared to the rest of the players for categories 2 and 3, showing in this last category the highest effect sizes (entire game, *d*=0.8-1.6; offense, *d*=0.4-1.1; defense, *d*=1.1-1.3).

The average maximum acceleration was also found for the wings, with medium to large size effects for the entire game (*d*=1.0-1.5) and the defensive phase (*d*=1.1-1.5), and medium for the offensive one (*d*=0.6-1.1).

Decelerations

In regard to decelerations, CBs showed the highest number of total decelerations (20-26% higher than the other backs and the LPs, *d*=0.3-0.7) and decelerations in the offensive phase (28-30% higher than wings and the other backs, *d*=0.5-0.7; 50% higher than LPs, *d*=1.2). In defense, wings presented the highest values (23-25% higher than backs, *d*=0.5-0.6). However, if we analyze the data segmented by categories, in categories 2 and 3 wings showed higher values than any other playing position with the highest effect sizes found in category 3 (entire game, *d*=0.3-0.9; offense, *d*=0.3-1.0; defense, *d*=0.3-0.4).

When analyzing normalized values, CBs and RBs were the ones presenting the higher total (20-35% higher, *d*=0.3-1.1) and offensive values (30-50% higher, *d*=0.2-1.5), while in defense no significant differences were found for any playing position. When analyzing by categories, wings



Note. Acc All=total accelerations; Acc All min=total accelerations per minute; AccOFF=accelerations in offense; AccOFF min=accelerations in offense per minute; AccDEF=accelerations in defense; AccDEF min=accelerations in defense per minute; Dec All=total decelerations; Dec All min=total decelerations per minute; Dec OFF=decelerations in offense; Dec OFF min=decelerations in offense per minute; Dec DEF=decelerations in defense; Dec DEF min=decelerations in defense per minute; BC All=total body contacts; BC All min=total body contacts per minute; BC OFF=body contacts in offense; BC OFF min=body contacts in offense per minute; BC DEF=body contacts in defense; BC DEF min=body contacts in defense per minute; Jum All=total jumps; Jum All min=total jumps per minute; Jum OFF=jumps in offense; Jum OFF min=jumps in offense per minute; Jum DEF=jumps in defense; Jum DEF min=jumps in defense per minute.

Figure 2. Effect sizes of the paired differences in the number of high intensity events per game between the different playing positions.

presented the highest values in category 3 for the entire game compared to LBs, CBs, and LPs (*d*=0.3-0.8) as well as for offense but only significant when compared to LPs (*d*=0.7). In defense, RWs showed the highest values compared to all the other playing positions including LWs (*d*=0.3-0.5).

Wings and CBs presented the highest values of average maximum decelerations for the entire game and offense (13-15% higher than LPs, *d*=0.9-1.0; 6-10% higher than LBs and RBs, *d*=0.5-0.7), while wings showed the highest values in defense (5% higher than CBs, *d*=0.3; 10-13% higher than LBs, RBs, and LPs, *d*=0.5-0.7).

Body contacts

CBs and LPs showed the highest number of body contacts in the entire game (55% higher than wings, *d*=0.8-1.3; 20% higher than RBs and LBs, *d*=0.2-0.3), with CBs showing the highest values in offense (73% higher than wings, *d*=1.4-1.5; 40% higher than LBs, RBs and LP, *d*=0.5-0.8), and LPs in defense (55% higher than RWs, *d*=0.9; 45% RBs, *d*=0.5; 35% LWs and RBs, *d*=0.2-0.5; 22% LBs; *d*=0.2). In category 3, LBs, RBs, and CBs showed the highest number of body contacts (55% higher than RWs, *d*=0.3-0.5).

According to time played, CBs and RBs received a higher average number of body contacts than wings (57%, *d*=0.4-1.4) in the entire game. Wings also presented the lowest values for offense with significant differences with the rest of the playing positions (80% less than RBs and CBs, *d*=0.5-1.8; 66% lower than LBs and LPs, *d*=0.4-1.0), and in defense with the LBs, RBs and LPs (60% lower, *d*=0.2-0.7). In category 3, there were no differences between the playing positions.

In regard to maximum body contacts, CBs and RBs showed higher values than the RWs in the entire game (*d*=0.7 and *d*=0.5, respectively) and offense (*d*=0.8 and *d*=0.6, respectively), while no significant differences were found in defense.

Jumps

LBs, RBs, and CBs were the players performing more total jumps per game (45% more than wings, *d*=0.6-1.0; 35% more than LPs, *d*=0.6-0.8) and in offense (44% more than wings, *d*=0.7-1.0; 66% more than LPs, *d*=1.2-1.5). In defense, LPs and LBs presented the highest values (50-60% higher than the rest, *d*=0.4-1.0). LBs and CBs showed the highest number of jumps in category 3 for the entire game and offense (LWs, RWs, and LPs, *d*=1.0-1.2; RBs, *d*=0.3-0.5). In defense, LPs were the ones presenting a higher number of jumps in this category (LWs, RWs, CBs, RBs, *d*=0.3-0.4).

Considering normalized data, LBs, RBs, and CBs still showed the highest average number of jumps per game and in offense (37-45%, *d*=0.3-1.5). In defense, LPs and LBs showed the highest values (+28-58%, *d*=0.2-0.9). These differences remained significant when analyzing separately category 2 (entire game, *d*=0.5-1.4; offense, *d*=0.5-1.7; defense, *d*=0.3-0.8) and category 3 (entire game, *d*=0.5-1.3; offense, *d*=0.5-1.4) but with higher effect sizes, except in defense where LPs only show significantly higher values than LW (*d*=0.2) and RW (*d*=0.3).

In regard to maximum jumps, LBs, RBs, and CBs also showed the highest values in the entire game (*d*=0.7-1.6) and offense (*d*=1.0-1.8), while no significant differences were found for defense.

Discussion and conclusions

The main goal of this study was to define and compare high intensity events' (HIE) demands of professional handball at the top-level championship by playing positions and the phase of the game. The HIE analyzed were players' accelerations, decelerations, body contacts, and jumps. To the best of our knowledge, this is the first time that the HIE performed by all players in all games through the entire EURO have been analyzed using an integrated system based on Sensors Network, LPS, and Big Data Analytics.

Accelerations and decelerations

Players' ability to accelerate and decelerate is particularly important in meeting tactical and technical demands in handball. Our results indicate that all players performed more high intensity accelerations (HIA) (over 2 m/s^2) than high intensity decelerations (HID) (under -2 m/s^2). This is in line with García et al. (2022) who found greater number of accelerations and covered distance during these actions than decelerations. This is also valid for different team sports like basketball, futsal, rink hockey or soccer. Harper et al. (2019) found that in all team sports apart, from American football, there seemed to be a greater frequency of high-intensity decelerations compared to accelerations. In contrast, Font et al. (2021) did not find differences in the number of accelerations and decelerations. In any case, handball induces one of the highest deceleration loads for players in team sports (Harper, et al., 2019). Therefore, we agree with Font et al. (2021) regarding the importance of monitoring decelerations due to their great involvement in the possibility of injury and overload of the player. Coaches should know and comprehensively monitor all the HIAs and HIDs as separate load indexes, as has been done in this study, and try to relate the data to the incidence of injuries in their teams.

In the present study, the wings and CBs performed more HIA and HID than the other positions on average in a match. In the highest intensity category (category 3), the wings were the ones that accelerated and decelerated the most at an absolute level. These data are in line with those obtained in other studies (Manchado, et al., 2013) but differ from those of Font et al. (2021), a study where CBs were the most active players, and González-Haro et al. (2020) and Luteberget et al. (2017) where the backs showed higher values for amateur men and elite women players, respectively.

In offense, wings and CBs again showed the highest number of HIA and HID, while LPs showed the lowest values. In defense, wings were the ones showing higher values than the rest of the players, followed by LPs. This fact perfectly reflects the game, the CBs and wings being the more dynamic players in offense and the LPs, having to play between the defenders, the more static ones. CBs are the organizers of the offensive game, and thus changes of pace are fundamental to overcome the defense, while wings, due to the space limitation of this position, need to show high acceleration and deceleration values to succeed. In defense, LPs are changed very often and when they defend, they usually show more activity in the center of the defense.

If we normalize the data according to the time spent on the court, the differences disappear for HIA in the whole match, due to less playing time for backs and LPs (Manchado, et al., 2021), a position that showed 30% fewer accelerations than the wings. These results are in line with those of Font et al. (2021). The normalized results for HIDs showed significant differences between the CBs and the wings (+25%) or the LPs (+35%) getting closer to those from Font et al. (2021) and Gonzalez de Haro et al. (2020). In offense, the RBs and CBs showed the highest load of HIA and HID compared to the other positions (almost 50% more than the LPs and approx. 30% more than all other playing positions). Greater involvement of these positions in tactical play could explain these higher values per minute played. In defense, results do not differ much from the absolute values.

Similarly to other studies (González-Haro, et al., 2020; Manchado et al., 2013), the maximum accelerations and decelerations presented by the wings in offense and defense were greater than in therest of the specific positions (around 20% difference), again possibly due to the space limitation of this position.

Body contacts

Concerning the body contacts, there are again clear differences between the playing positions. In this case, CBs and LPs are the positions that receive more high intensity body contacts (HIBC) during the whole match and the wings the least. Back players receive the highest number of hard body contacts. These results are partially in line with those of Gonzalez de Haro et al. (2020) who also showed the CBs and LPs as the positions with more HIBD, although in our study the differences with the wings are greater, probably because we also included the defense phase data.

In the offensive phase, the CBs received significantly more body contacts than the rest of the players and wings the least. The CB is the one that plays the most in proximity to the defense and with the greatest defensive pressure since the CB is the main builder of the offense. This trend of greater participation of the CB is even clearer when analyzing by categories of global intensity (50% of the average in category 2 and 40% in category 3).

In defense, the LPs are the ones that executed the most body contacts and again the wings the least. This could be due to the position the LPs normally occupy in central areas of defensive systems. For the same reason, the LBs also showed more body contacts than the rest of the players (15% more than the average). These differences, with some nuances, were maintained when analyzed more deeply by high-intensity categories (categories 2 and 3). When normalizing by time played, there were no longer differences between the LBs and RBs, the positions that also have a very important role in defense.

Jumps

The backs showed significantly more jumps per game and in offense. This behavior is clearer in intensity categories 2 and 3 where the differences in some cases increase above 75%. These results are in line with Povoas et al. (2014) showing backcourt players 60% higher values than wings (19.1±5.2 vs 8.2±2.9). The total number of jumps in our study is higher (8.6) compared to amateur players' studies. Chelly et al. (2011), Gonzalez de Haro et al. (2020), and Povoas et al. (2012) found values of 6.9, 4.3 and 4.9 jumps per player during the match, respectively. Probably, the high demands of the EURO are responsible for the differences. Back players are not only jumping more but they are also the ones performing the highest jumps in the entire game and offense. Due to the tactical needs of the game to overcome defensive barriers, the number and intensity of jumps made by the backs are higher. In defense, the LBs and LPs showed more jumps and the wings, especially the RWs, the least. The LPs were the ones presenting a higher number of jumps in category 3, probably because they usually occupied central defensive positions thus having to jump when trying to block shots taken by the opposing backcourt players.

Limitations

One of the limitations we have found is that the comparison between studies is complicated. The number of investigations with a similar aim is very limited and those that have been carried out are analyzing different populations with different instruments. Another limitation is that the tactical playing systems and playing styles used have not been taken into consideration, which would undoubtedly have influenced the load differentiation as they play a crucial role in performance (Abdelkrim, Castagna, El Fazaa, & El Ati, 2010). It would be interesting to know, for example, how the use of a 5:1 defense influences HIE as opposed to a 6:0. Furthermore, although the Kinexon system has been validated previously, body contacts and jumps as well as the different categories established have not been validated specifically.

Practical applications

The results of the present study represent possible reference values for male elite handball players. In this sense, wings presented the highest absolute values of HIA and HID. Coaches should consider bringing to specific tournaments like the European Championship an extra wing player or a polyvalent player, distribute better the minutes played over the competition in this position avoiding excessive fatigue and possible injuries. Backs and LPs should train with lower volumes but at higher intensities. Traditionally, CBs have been included in the group of backs, but actually, their external load is more similar to that of the wings. Therefore, it would be appropriate to establish at least three working groups: CBs and wings, backs, and LPs. Finally, the differences found between the players regarding offense and defense should also be considered, establishing different training programmes accordingly.

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Declaration of interest

The authors report there are no competing interests to declare.

Supplemental Digital Content: Mean, standard deviation and statistical differences from the ANOVA in the three subcategories of each high intensity event normalized by time played

	LW 2	LB 3	CB 4	RB 5	RW 6	LP 7
AccT/min	1.69±0.25^{7}	1.45±2.93	1.62±0.59^{7}	1.82±4.00	1.71±1.67^{7}	1.20±0.36^{246}
Cat 1	0.91±0.30	1.10±2.23	1.20±0.40^{267}	1.36±2.88	0.87±0.68	0.87±0.31
Cat 2	0.63±0.25^{3457}	0.31±0.58^{6}	0.38±0.24^{67}	0.42±1.09^{6}	0.70±0.91^{3457}	0.30±0.21^{246}
Cat 3	0.15±0.12^{3457}	0.04±0.15	0.04±0.06^{7}	0.04±0.17	0.15±0.21^{3457}	0.02±0.04
AccOff/min	1.07±0.33^{47}	1.04±2.84	1.33±0.61^{267}	1.38±3.26^{7}	1.09±0.91^{7}	0.69±0.40^{2456}
Cat 1	0.55±0.22^{7}	0.75±2.10	0.96±0.41^{267}	0.99±2.27^{267}	0.54±0.42	0.48±0.29
Cat 2	0.43±0.20^{347}	0.24±0.58^{6}	0.34±0.24^{67}	0.34±0.95^{6}	0.48±0.54^{7}	0.18±0.21
Cat 3	0.08±0.09^{3457}	0.03±0.15	0.03±0.06^{7}	0.03±0.17	0.08±0.16^{357}	0.01±0.04
AccDef/min	0.63±0.25^{347}	0.46±0.31^{47}	0.32±0.19^{67}	0.48±0.91	0.66±0.80	0.57±0.28
Cat 1	0.36±0.17^{4}	0.36±0.28^{4}	0.24±0.17	0.38±0.73	0.34±0.29^{4}	0.42±0.23^{34}
Cat 2	0.20±0.11^{3457}	0.08±0.09^{467}	0.05±0.06^{67}	0.08±0.21^{67}	0.23±0.41^{7}	0.12±0.11
Cat 3	0.07±0.07^{3457}	0.01±0.02	0.01±0.02	0.01±0.03	0.08±0.14^{3457}	0.01±0.02
DecT/min	1.06±0.33^{47}	1.15±1.69^{47}	1.42±0.56^{67}	1.37±2.25^{7}	1.05±0.85	0.92±0.33
Cat 1	0.77±0.25	0.92±1.13	1.08±0.43^{267}	1.08±1.69^{67}	0.74±0.72	0.75±0.26
Cat 2	0.24±0.14^{47}	0.21±0.44^{4}	0.29±0.20^{7}	0.26±0.59	0.25±0.19^{7}	0.16±0.16
Cat 3	0.04±0.06^{57}	0.02±0.14^{6}	0.03±0.05^{567}	0.02±0.05^{6}	0.06±0.08^{7}	0.01±0.04
DecOff/min	0.63±0.25^{47}	0.78±1.42^{7}	1.05±0.44^{67}	0.96±1.82^{7}	0.65±0.43^{7}	0.52±0.25
Cat 1	0.44±0.19	0.61±1.00	0.81±0.37^{2367}	0.74±1.26^{267}	0.43±0.35	0.41±0.19
Cat 2	0.16±0.11^{47}	0.14±0.30^{4}	0.21±0.15^{67}	0.21±0.58^{7}	0.17±0.14^{7}	0.09±0.11
Cat 3	0.03±0.05^{57}	0.02±0.14	0.02±0.04^{57}	0.01±0.04	0.04±0.07^{457}	0.01±0.02
DecDef/min	0.44±0.17^{4}	0.39±0.32	0.37±0.20	0.42±0.49	0.43±0.47	0.41±0.16
Cat 1	0.34±0.15^{4}	0.31±0.21	0.28±0.15	0.35±0.47	0.32±0.41	0.34±0.15^{4}
Cat 2	0.08±0.07	0.06±0.16	0.08±0.09	0.05±0.07^{246}	0.08±0.09	0.07±0.08
Cat 3	0.01±0.02	0.01±0.02	0.01±0.03	0.01±0.02	0.02±0.04^{2357}	0.01±0.03
ImpactsT/min	1.31±0.95^{3457}	2.69±2.41^{467}	2.50±0.94^{67}	2.85±5.02^{67}	1.13±1.36^{7}	3.89±1.40
Cat 1	0.23±0.18	0.49±0.50^{26}	0.56±0.27^{26}	0.56±0.93^{26}	0.19±0.24	0.53±0.26^{26}
Cat 2	0.04±0.06^{3457}	0.10±0.18^{46}	0.13±0.10^{67}	0.14±0.34^{6}	0.04±0.14^{7}	0.08±0.08
Cat 3	0.01±0.04	0.02±0.07	0.02±0.04	0.03±0.16	0.01±0.02^{346}	0.01±0.03
ImpactsOff/min	0.50±0.30^{3457}	1.09±1.89^{467}	1.65±0.73^{67}	1.40±2.12^{67}	0.50±0.78^{7}	2.06±1.43
Cat 1	0.09±0.10	0.27±0.45^{26}	0.42±0.22^{2367}	0.35±0.54^{26}	0.09±0.12	0.27±0.22^{26}
Cat 2	0.02±0.04^{3457}	0.07±0.16^{46}	0.11±0.09^{67}	0.11±0.34^{67}	0.02±0.07^{7}	0.05±0.06
Cat 3	0.01±0.03^{4}	0.02±0.04	0.02±0.03^{7}	0.02±0.16	0.00±0.01^{347}	0.01±0.02
ImpactsDef/min	0.85±0.85^{357}	1.65±1.33^{46}	0.90±0.81^{67}	1.49±3.15^{6}	0.68±0.66^{7}	1.90±1.12
Cat 1	0.14±0.14	0.23±0.28^{246}	0.14±0.15	0.22±0.47^{6}	0.10±0.16	0.26±0.18^{246}
Cat 2	0.02±0.03^{3}	0.03±0.07	0.02±0.04	0.03±0.04	0.02±0.08	0.04±0.05^{245}
Cat 3	0.00±0.02	0.01±0.05	0.00±0.01	0.01±0.02	0.00±0.01	0.01±0.02
Jumps/min	0.21±0.13^{345}	0.42±0.45^{67}	0.40±0.22^{67}	0.54±1.29^{67}	0.21±0.49	0.24±0.14
Cat 1	0.13±0.09	0.14±0.29	0.13±0.11	0.15±0.48	0.13±0.39	0.15±0.10
Cat 2	0.05±0.07^{345}	0.14±0.17^{67}	0.15±0.11^{7}	0.18±0.33^{67}	0.03±0.04^{7}	0.06±0.07
Cat 3	0.02±0.03^{3457}	0.12±0.12^{567}	0.10±0.10^{567}	0.20±0.49^{67}	0.02±0.07^{7}	0.01±0.03
JumpsOff/min	0.15±0.10^{3457}	0.34±0.47^{67}	0.34±0.20^{67}	0.48±1.15^{67}	0.18±0.43	0.11±0.09
Cat 1	0.10±0.08^{7}	0.08±0.29	0.10±0.10^{7}	0.11±0.33	0.10±0.33	0.07±0.07
Cat 2	0.02±0.04^{3457}	0.10±0.16^{67}	0.13±0.10^{67}	0.16±0.33^{67}	0.03±0.04^{7}	0.01±0.03
Cat 3	0.01±0.03^{3457}	0.11±0.11^{67}	0.09±0.09^{567}	0.19±0.49^{67}	0.02±0.07^{7}	0.00±0.02
JumpsDef/min	0.09±0.07^{37}	0.15±0.12^{46}	0.09±0.08^{7}	0.11±0.20^{7}	0.08±0.10^{7}	0.17±0.11
Cat 1	0.03±0.05	0.06±0.08^{246}	0.03±0.05	0.05±0.17	0.03±0.08	0.08±0.082^{23456}
Cat 2	0.02±0.04^{367}	0.04±0.06^{456}	0.02±0.04^{67}	0.02±0.04^{67}	0.01±0.02^{7}	0.05±0.06
Cat 3	0.00±0.01	0.01±0.02^{6}	0.01±0.02	0.01±0.03	0.00±0.01	0.01±0.02^{26}

AccT/min=total accelerations per minute; AccOff/min=Accelerations in offense per minute; AccDef/min=Accelerations in defense per minute; DecT/min= total decelerations per minute; DecOff/min=decelerations in offense per minute; DecDef/min=decelerations in defense per minute; ImpactsT/min=total impacts per minute; ImpactOff/min=impacts in offense per minute; ImpactDef/min=impacts in defense per minute; JumpsT/min=total jumps per minute; JumpOff/min=jumps in offense per minute; JumpDef/min=Jumps in defense per minute; Cat 1=category 1; Cat 2=category 2; Cat 3=Category 3; p>.05 for superscripts numbers.

Supplemental Digital Content: Mean, standard deviation and statistical differences from the ANOVA in the three subcategories of each high intensity event normalized by time played

TOTAL	LW 2	LB 3	CB 4	RB 5	RW 6	LP 7
Acc	56.04±28.10^{3457}	34.85±18.44	43.90±20.98^{357}	36.75±16.97	51.51±29.91^{457}	33.90±17.86
Cat 1	30.43±16.41^{37}	26.44±14.09^{3567}	32.78±15.47	28.57±14.20^{7}	27.17±16.65	25.23±14.16
Cat 2	21.05±12.20^{3457}	7.53±5.72^{4}	10.26±6.58^{57}	7.64±4.54	20.41±12.84^{3457}	8.10±5.59
Cat 3	4.57±3.95^{3457}	0.66±1.04	0.86±1.28^{567}	0.55±0.94	3.93±3.65^{3457}	0.48±0.95
AccOff	35.39±18.65^{357}	23.34±15.76^{7}	35.55±18.55^{357}	27.15±14.03^{7}	32.21±18.83^{37}	18.20±11.36
Cat 1	18.31±10.47^{7}	16.81±11.71^{7}	25.97±13.37^{23567}	20.35±11.33^{367}	16.85±10.74^{7}	12.87±8.82
Cat 2	14.43±9.03^{3457}	5.41±4.96^{4}	8.73±6.10^{57}	6.05±4.26^{7}	13.74±9.09 ^{3457}	4.43±4.11^{456}
Cat 3	2.49±2.70^{34567}	0.47±0.92^{7}	0.70±1.23^{57}	0.41±0.77	1.64±2.17^{3457}	0.25±0.68^{23456}
AccDef	21.22±10.90^{3457}	12.62±8.93^{457}	9.50±6.64^{7}	10.44±6.89^{7}	20.57±11.52^{3457}	17.53±11.83
Cat 1	12.23±7.38^{345}	9.88±7.08^{4}	7.07±5.53	8.42±5.82	10.82±6.71^{4}	12.91±9.30^{3456}
Cat 2	6.67±4.19^{3457}	2.18±2.64^{4567}	1.59±1.98^{67}	1.63±1.68^{67}	6.98±4.67^{7}	3.83±3.65
Cat 3	2.10±2.06^{3457}	0.19±0.48	0.17±0.48	0.14±0.48	2.39±2.26 ^{3457}	0.24±0.68
DecT	34.46±17.98^{357}	28.37±15.61^{4}	38.87±19.44^{567}	29.56±15.02^{7}	32.02±20.09^{7}	26.01±13.79
Cat 1	25.48±13.48^{7}	23.29±12.94	29.91±15.04^{23567}	23.61±12.23	22.37±14.24	21.45±11.78
Cat 2	7.75±5.46^{357}	4.62±3.81^{46}	7.92±5.53^{57}	5.34±3.85^{67}	7.92±6.13^{7}	4.15±3.50
Cat 3	1.23±1.39^{3457}	0.37±0.80	0.89±1.11^{357}	0.48±0.85^{7}	1.59±1.83^{3457}	0.27±0.79
DecOff	20.78±12.58^{47}	18.55±11.43^{47}	28.73±15.31^{567}	19.91±10.59^{7}	19.68±13.26^{7}	14.42±8.34
Cat 1	14.68±9.26^{7}	14.80±9.37^{7}	22.17±12.00^{23567}	15.49±8.56^{67}	13.06±9.01	11.65±7.10
Cat 2	5.19±4.23^{357}	3.26±2.87^{467}	5.80±4.26^{57}	3.95±3.07^{67}	5.40±4.71^{7}	2.48±2.50
Cat 3	0.91±1.13^{357}	0.25±0.58^{467}	0.64±0.89^{567}	0.31±0.63^{67}	1.05±1.40^{7}	0.13±0.48
DecDef	14.01±7.29^{3457}	10.22±6.49^{67}	10.40±5.70^{6}	9.89±6.22^{67}	12.88±8.21	11.77±6.53
Cat 1	10.90±6.02^{345}	8.67±5.92	7.90±4.72	8.16±5.48	9.69±6.40^{4}	9.91±5.88^{45}
Cat 2	2.59±2.16^{357}	1.38±1.63	2.18±2.08^{357}	1.41±1.42	2.64±2.24^{357}	1.69±1.71
Cat 3	0.32±0.54^{3567}	0.12±0.41	0.26±0.56^{3}	0.18±0.44	0.56±0.86 ^{3457}	0.14±0.51
Impacts	9.86±8.09	15.73±10.02^{26}	20.14±11.99^{2356}	16.52±9.27	7.59±5.32	18.07±10.72^{236}
Cat 1	7.64±6.40	12.53±7.61^{27}	15.80±9.73^{2356}	12.82±7.65^{27}	5.49±4.55	15.17±9.30^{2356}
Cat 2	1.40±1.92^{3457}	2.40±2.87^{46}	3.69±3.00^{567}	2.94±2.42^{67}	1.12±1.47^{7}	2.31±2.08
Cat 3	0.36±1.33	0.56±1.54	0.58±0.80	0.50±0.88	0.21±0.48^{3457}	0.40±0.71
ImpactsOff	4.23±4.30	8.37±6.66^{26}	15.53±10.03^{23567}	10.80±6.93^{2367}	3.90±3.49	8.98±7.30^{26}
Cat 1	3.03±2.87	6.40±5.23^{26}	11.85±7.92^{23567}	8.03±5.52^{26}	2.82±2.90	7.38±6.16^{26}
Cat 2	0.74±1.29^{3457}	1.49±1.87^{456}	3.13±2.71^{567}	2.24±2.09^{67}	0.59±0.93^{7}	1.26±1.56
Cat 3	0.26±1.08	0.36±0.78	0.49±0.72^{7}	0.36±0.68	0.11±0.32^{3457}	0.25±0.57
ImpactsDef	5.63±5.31^{6}	7.35±6.88^{2456}	4.60±5.16	5.72±4.79^{6}	3.69±3.04	9.08±7.10^{23456}
Cat 1	4.65±4.67^{6}	6.27±5.38^{2456}	4.08±4.50^{6}	4.87±4.18^{6}	2.79±2.55	8.03±6.18^{23456}
Cat 2	0.66±1.08	0.93±1.71^{46}	0.58±1.03	0.72±0.99	0.56±0.96	1.09±1.29^{2456}
Cat 3	0.11±0.41	0.21±0.99	0.08±0.29	0.15±0.43	0.11±0.36	0.16±0.44
Jumps	6.68±4.89^{345}	10.86±7.33^{67}	11.36±7.75^{67}	12.09±7.65^{67}	5.76±3.98^{7}	7.18±4.80
Cat 1	4.12±2.95^{5}	3.51±3.22	3.64±3.05	3.28±2.62	3.46±2.89	4.38±3.24^{345}
Cat 2	1.53±2.25^{345}	3.76±3.34^{67}	4.40±3.62^{67}	4.25±3.42^{67}	1.12±1.47^{7}	1.83±2.17
Cat 3	0.56±1.38^{345}	3.24±3.21^{567}	2.87±2.97^{567}	4.26±3.89^{67}	0.58±0.93	0.44±1.01
JumpsOff	4.62±3.38^{3457}	8.37±5.70^{567}	9.61±6.84^{67}	10.43±6.77^{67}	4.86±3.27^{7}	3.22±2.43
Cat 1	3.01±2.34^{357}	1.66±1.87	2.79±2.44^{357}	2.21±1.87^{3}	2.79±2.54^{37}	2.02±2.01
Cat 2	0.76±1.41^{3457}	2.64±2.71^{4567}	3.68±3.26^{67}	3.62±3.16^{67}	0.82±1.21^{7}	0.32±0.69
Cat 3	0.41±1.13	3.01±3.12	2.72±2.88	4.14±3.79	0.48±0.82	0.13±0.58
JumpsDef	2.90±2.41^{367}	4.32±4.51^{456}	2.99±3.07^{67}	2.70±1.97^{67}	1.99±1.23^{7}	5.31±3.78
Cat 1	1.12±1.41^{6}	1.90±2.56^{2456}	0.88±1.44	1.10±1.52^{6}	0.69±0.98	2.47±2.41^{23456}
Cat 2	0.77±1.34	1.15±1.99^{56}	0.75±1.51	0.65±0.99^{3}	0.30±0.59^{23457}	1.57±1.99^{245}
Cat 3	0.15±0.46	0.24±0.58^{6}	0.15±0.48	0.13±0.38	0.11±0.32	0.33±0.78^{2456}

AccT=total accelerations; AccOff=Accelerations in offense; AccDef=Accelerations in defense; DecT= total decelerations; DecOff=decelerations in offense; DecDef=decelerations in defense; ImpactT=total impacts; ImpactOff=impacts in offense; ImpactDef=impacts in defense; JumpsT=total jumps; JumpsOff=jumps in offense; JumpsDef=Jumps in defense; Cat 1=category 1; Cat 2=category 2; Cat 3=Category 3; p>0.5 for superscripts numbers.