Artículo original / Original Article

EXTERNAL AND INTERNAL LOAD OF COSTA RICAN HANDBALL REFEREES ACCORDING TO SEX AND GAME PERIODS

Carga externa e interna de árbitros costarricenses de balonmano en función del sexo y periodo de juego

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Recibido: 19/01/2020; **Aceptado:** 11/05/2021; **Publicado**: 15/07/2021

OPEN ACCESS

Sección / Section:
Análisis del rendimiento deportivo / Performance analysis in sport

Editor de Sección / Edited by:
Sebastián Feu, Universidad de Extremadura, España

Citación / Citation:
Gutiérrez-Vargas, R., Ugalde-Ramírez, J. A, Rojas-Valverde, D., Müller-Thyssen, M., & Pino-Ortega, J. (2021). External and internal load of Costa Rican handball referees according to sex and game periods. *E-balonmano Com 17*(2), 153-162.

Fuentes de Financiación / Funding:
No funding reported by authors.

Agradecimientos/ Acknowledgments:
To all the referees, players, and coaches of the eight teams that participated in this study.

Conflicto de intereses / Conflicts of Interest: NO

Abstract

The purpose of this study was to analyze the external and internal load of Costa Rican handball referees according to sex and game periods. Nine referees (6 men and 3 women) were monitored during U19 handball matches, using an ultra-wide band local positioning system (UWB) and WIMUPro™ inertial units (IMU). The results showed a total distance of 4566.54±494.02 m (46.95% at 0-6 km/h, 32.97% at 6-12 km/h, 18.11% at 12-18 km/h and 1.96% >18 km/h). 1298.34±151.42 m/s^2 accelerations and 1297.73±152.09 m/s^2 decelerations were performed. Maximal speed was 19.63±1.85 km/h and average speed was 4.80±0.34 km/h. Player Load$_{RT}$ was 50.53±9.39 UA. Maximal and average heart rate was 170.59±18.20 bpm 143.06±16.94 bpm respectively. 60% of the efforts were <80% of maximum heart rate. Total energy expenditure was 372.34±67.80 kcal. No significant differences were found in physiological variables between sexes, although men covered greater distance at 0-6 km/h. In the second periods the total distance (m/min), distance at 6-12 km/h, 12-18 km/h (m/min) and >18 km/h, average speed, impacts at 3-5g and >5g, Player Load$_{RT}$, and energy expenditure decreased. In conclusion, sex does not seem to affect the external or internal load, while the game period influenced on the external load.
Keywords: handball; referees; game periods; sex.

Resumen

El propósito de este estudio fue analizar la carga externa e interna de árbitros costarricenses de balonmano según sexo y periodos de juego. Nueve árbitros (6 hombres y 3 mujeres) fueron monitoreados durante partidos de balonmano Sub-19, utilizando un sistema de posicionamiento local de banda ultra ancha (UWB) y unidades inerciales WIMUPro™(IMU). Los resultados mostraron una distancia total de 4566.54±494.02 m (46,95% a 0-6 km/h, 32,97% a 6-12 km/, 18,11% a 12-18 km/h y 1,96% a >18 km/h. Se realizaron 1298.34±151.42 m/s^2 aceleraciones y 1297.73±152.09 m/s^2 desaceleraciones. La velocidad máxima fue 19.63±1.85 km/h y la velocidad promedio fue 4.80±0.34 km/h. Player LoadRT fue 50.53±9.39 UA. La frecuencia cardíaca máxima y promedio fueron 170.59±18.20 lpm y 143.06±16.94 lpm respectivamente. El 60% de los esfuerzos fueron <80% de la frecuencia cardíaca máxima. El gasto energético total fue 372.34±67.80 kcal. No hubo diferencias significativas en variables fisiológicas entre sexos, aunque los hombres recorrieron mayor distancia a 0-6 km/h. En los segundos periodos la distancia total (m/min), distancia a 6-12 km/h, 12-18 km/h (m/min) y >18 km/h, velocidad media, impactos a 3-5 g y > 5g, Player Load$_{RT}$ y gasto energético disminuyeron. En conclusión, el sexo no parece afectar la carga externa o interna, mientras que el periodo de juego sí influyó en la carga externa.
Palabras claves: balonmano; árbitros; periodos de juego; sexo.

Introduction

Nowadays in sport and specially in handball playing, referees have a critical role in managing the dynamics of the game. They are in charge of ensuring compliance with the regulations during matches (Prat Grau et al., 2013). The referees are responsible for making crucial decisions for both teams objectively (Bloß et al., 2020). In order to achieve these objectives, the referees must have extensive knowledge of the regulations, well-developed psychological and perceptual skills, as well as optimal physical abilities that allow them to move around the court throughout a match to place themselves in a timely and correct manner in each action, to have sufficient criteria to solve each play in the best way possible (Riiser et al., 2019).

In recent years, the study of referees' behavior has aroused great interest among sports scientists. Increasing research has developed to quantify and describe the external and internal load that this in-field function represents. The monitoring of referees during games has been developed both in outdoor sports such as football (Boullosa et al., 2012; Castillo et al., 2016; Castillo et al., 2016; Mallo et al., 2006; Weston, 2015; Yanci-Irigoyen, 2014) as well as in indoor sports as basketball (Ali Nabli et al., 2017; García-Santos et al., 2020; García-Santos et al., 2019; Rojas-Valverde et al., 2020), futsal (Ahmed et al., 2017; Ahmed et al., 2020; Dixon, 2014; Rebelo et al., 2011) and handball (Fernandes da Silva et al., 2010; García-Santos et al., 2017).

Handball is an acyclical sport with positional periods and explosive physical actions both in attack and defense (Madou, 2020) that requires high intensity for its development. It has been reported in world championship matches, that the players perform an average speed of 7.7 ± 0.8 m/s (Cardinale et al., 2017). The distances covered by the players during matches according to the different speed ranges have been reported to be 39.2% walking (<4 km/h), 17% jogging (7-8 km/h), 14.1% running (12-13 km/h), 5.7% in high intensity running (15.5-17 km/h) 2.2% at sprint speeds (22-24 km/h), 18.4% in lateral movements (9-10 km/h) and 3.4% in reverse travel (9-10 km/h) (Michalsik et al., 2013). This locomotion characteristics of players may have an impact on how referees they move and locate themselves in the field in relation to their positioning and the physical demands required to get into a position that can clearly judge actions.

Handball matches are directed by two referees, who move around the court according to the demands of the game. In a handball match, physical contact between players is very frequent due to clashes for ball disputes, as well as when scoring and blocking (Souchon et al., 2009, 2016). Given this, refereeing handball matches demands high concentration, determination and significant physical effort (Fernandes da Silva et al., 2010).

There are few studies that have addressed the physical demands of referees at different levels. A study quantified the external and internal load of two referees in two final matches for children and cadets of Spanish teams (García-Santos et al., 2017). This study showed that during 40 minutes of play the total distance covered by the referees ranged between 3347 and 4415 m (64 and 86 m/min), 94.5% of this distance was covered at an intensity of 0-7 km/h and a 5.5% at an intensity of 7-14 km/h, the maximum speed was 13.8 km/h, the average speed was 2.4 km/h, and the number of accelerations was 2392 (46.3 acc/min) and decelerations of 2365 (45.8 dec/min) (García-Santos et al., 2017). The internal load of the referees has also been reported; Brazilian referees who were evaluated in four matches of the local men's league presented a maximum heart rate of 193 bpm and an average hear rate of 131 bpm. Besides, of the total playing time, 96.4% predominated moderate intensity and 3.6% were categorized as heavy or severe (Fernandes da Silva et al., 2010).

Considering the lack of information reported to date about the physical loads of handball referees worldwide, specifically when exploring the potential differences with respect to sex and depending on the playing period, more information is needed. Therefore, conducting an investigation in this line could provide data that can be considered to improve training plans, design more specific physical tests and help to prevent sports injuries in referees. Consequently, the purpose of this study was to analyze the external load (kinematic and neuromuscular behaviors) and the internal load (physiological demands) of Costa Rican handball referees according to sex and game periods.

Methodology

Participants

Nine Costa Rican handball referees (six men and three women) participated during U-19 youth congested fixture tournament. The average age of the referees was 30.5 ± 10.1 years, the average months of refereeing experience was 46.3 ± 22.6 months. Regarding the anthropometric characteristics, the referees presented a body mass of 72.8 ± 9.02 kg and a height of 1.65 ± 0.08 m.

The referees were informed about the objectives and methodology of the investigation. All signed an informed consent which outlined the benefits and potential risks of their participation. This study considered the ethical principles of the Declaration of Helsinki issued by the World Medical Association (2013).

Instruments and procedures

A local positioning system based on *ultra-wide band* (UWB) technology was set using six antennas that were placed in a hexagonal configuration around the handball pitch (WIMUPro™, RealTrack Systems, Almería, Spain). Inertial Measurement Units (IMUs) (WIMUPro™, RealTrack Systems, Almería, Spain) were used to quantify the kinematic behaviors performed by the referees during the matches, the devices were attached at the inter-scapulae level (T2-T4) using a special neoprene harness. Heart rate was measured by a heart monitor (HRM3-SS, Garmin Ltd, Olathe, KS, USA) linked to the IMU device. Through the SPro™ software (RealTrack Systems, Almería, Spain) the data were downloaded immediately after each game and the data subsequently analyzed. All games were played under official IHF rules (40x20 m pitch, two periods of 30 min) and federated referees. The games are systematically scheduled at a similar time of the day for each team to avoid inter day´s rest bias. Data was collected during an official regional tournament (3 consecutive days, 8 teams, 12 matches) organized in Costa Rica. Teams were divided into two groups by sex.

The ultra-wideband system was developed following previous validated and reliable methods (Bastida Castillo, Gómez Carmona, De la Cruz Sánchez, & Pino Ortega, 2018) and in specific handball studies (Bastida-Castillo, Gómez-Carmona, Hernandez, & Pino-Ortega, 2018). The microelectromechanical sensors were calibrated following previous research to achieve acceptable reliability and validity during testing (Gómez-Carmona, Pino-Ortega, Sánchez-Ureña, Ibáñez, & Rojas-Valverde, 2019). These systems report a well precision and reliability for the analysis of kinematic behaviors (Bastida-Castillo et al., 2019) and for recording heart rate (Molina-Carmona et al., 2018) in sports indoors.

External load variables

The variables related to external load were divided into kinematic and neuromuscular variables as they have been analyzed in previous works (García-Santos et al., 2017; García-Santos et al., 2019). *The kinematic variables* were the following: total distance traveled in meters, distance traveled at different intensities: 0-6 km/h, 6-12km/h, 12-18 km/h and >18 km/h. The number of accelerations and decelerations. All these variables were expressed in absolute and relative values (meters traveled per minutes played). The maximum and average speed expressed in kilometers per hour (km/h) reached during the match was also measured.

The neuromuscular variables were the following: total number of impacts received and those received at different categories of g forces (1 g= 9.8 m^{-2}): 0-3 g, 3-5 g and >5 g. The Player $Load_{RT}$, which represents the physical stress experienced by the referee by the magnitudes of the lateral, vertical and anteroposterior accelerations was also evaluated. Calculated by the following equation:

$$Player\ Load_{RT} = \sum \sqrt{\frac{(\mathrm{X_n} - \mathrm{X_{n-1}})^2 + (\mathrm{Y_n} - \mathrm{Y_{n-1}})^2 + (\mathrm{Z_n} - \mathrm{Z_{n-1}})^2}{100}}$$

Where the sum of the numbers of lateral accelerations (X_n), vertical (Y_n) anteroposterior (Z_n) at the moment and also the numbers of lateral accelerations (X_{n-1}), vertical (Y_{n-1}) anteroposterior (Z_{n-1}) in the previous moment. These variables were reported in absolute and relative values (values divided by the minutes played).

Internal load variables

These variables are represented by the physiological responses and were the following: maximal heart rate (HRmax) and average in beats per minute (beats/minute). Five intervals were established to analyze the percentage of work in relation to HRmax: 50-60% HRmax, 60-70% HRmax, 70-80% HRmax, 80-90% HRmax and >90% HRmax. The energy expenditure expressed in kilocalories was also evaluated both in absolute (kcal) and relative (kcal per minute) values.

Statistical analysis

Firstly, Shapiro-Wilks tests were applied to assess the normality of the data ($p > 0.05$). Repeated-measures t-tests to find out differences in the external and internal load between the first and second half were applied, to compare the data according to sex, independent groups t-tests were applied. To interpret the magnitude of the differences, Cohen's d was calculated and interpreted as: small when $d > 0.2$ moderate when $d > 0.5$ and large when $d > 0.8$ (Cohen, 1988). The data are reported in averages and their respective standard deviations. For all analyzes, the level of significance considered was $p<0.05$. Statistical software for social sciences (SPSS, Chicago, IL, USA, version 23) was used to analyze the data.

Results

The descriptive analysis shows that the handball referees per game covered an average total distance of 4566.54 ± 494.02 m (66.17 ± 7.75 m/min), of which 46.95% was performed at a speed of 0-6 km/h, 32.97% between 6-12 km/h, 18.11% between 12-18 km/h and 1.96% higher than 18 km/h. The number of accelerations and decelerations were 1298.34 ± 151.42 (18.80 ± 2.13 n/min) and 1297.73 ± 152.09 (18.79 ± 2.15 n/min). The maximum speed reached was 19.63 ± 1.85 km/h, and the average speed was 4.80 ± 0.34 km/h. The total number of impacts was 6730.30 ± 1382.48 (97.32 ± 19.14 n/min) of which 82.25% were of a magnitude less than 3 g, 12.51% between 3-5 g and 5.23 were greater than 5 g. The Player $Load_{RT}$ was on average 50.53 ± 9.39 au (0.73 ± 0.14 au/min).

The maximal and average heart rate were 170.59 ± 18.20 and 143.06 ± 16.94 beats/minute, respectively. The percentage of efforts performed according to the heart rate zones were the following: 13.3% between the 50-60% zone, 29.6% between the 60-70% zone, 35.2% between the 70-80% zone, 17.7% between the 80-90% zone, and 1.9% higher than 90%. Energy expenditure was shown: 372.34 ± 67.80 kcal (5.31 ± 1.00 kcal/min).

Table 1 shows the data according to sex and there is statistically significant in the distance traveled at a speed between 0-6 km/h both in absolute and relative values, which is higher in men than in women.

Table 1. Absolute and relative data of the external load variables (kinematic and neuromuscular) evaluated according to the sex of the referees.

Kinematic variables	Women	Men	*t*	*p*	*d*
Total distance (m)	4388.91 ± 240.97	4625.74 ± 547.36	-0.925	0.367	0.47^{S}
Total distance (m/min)	62.60 ± 2.08	67.36 ± 8.40	-2.020	0.059	0.64^{M}
Distance 0-6 km/h (m)	1986.77 ± 173.83	2196.61 ± 192.65	-2.154	0.045*	1.09^{L}
Distance 0-6 km/h (m/min)	28.33 ± 2.08	31.99 ± 3.07	-2.462	0.024*	1.25^{L}
Distance 6-12 km/h (m)	1464.09 ± 196.16	1519.37 ± 276.26	-0.411	0.686	0.21^{S}
Distance 6-12 km/h (m/min)	20.86 ± 2.40	22.12 ± 4.06	-0.648	0.525	0.33^{S}
Distance 12-18 km/h (m)	868.80 ± 98.42	813.24 ± 222.07	0.535	0.599	0.27^{S}
Distance 12-18 km/h (m/min)	12.41 ± 1.47	11.85 ± 3.33	0.515	0.614	0.18^{S}
Distance >18 km/h (m)	69.25 ± 46.02	96.53 ± 73.52	-0.773	0.450	0.39^{S}
Distance >18 km/h (m/min)	1.00 ± 0.68	1.40 ± 1.06	-0.791	0.439	0.40^{S}
Total accelerations (n)	1234.02 ± 188.10	1319.77 ± 137.97	-1.103	0.285	0.55^{M}
Total accelerations (n/min)	17.63 ± 2.88	19.18 ± 1.78	-1.447	0.165	0.71^{M}
Total decelerations (n)	1234.68 ± 188.31	1318.75 ± 139.16	-1.075	0.297	0.53^{M}
Total decelerations (n/min)	17.64 ± 2.89	19.17 ± 1.80	-1.412	0.175	0.69^{M}
Maximal speed (km/h)	18.35 ± 1.42	20.06 ± 1.81	-1.910	0.072	0.97^{M}
Average speed (km/h)	4.92 ± 0.35	4.76 ± 0.34	0.897	0.382	0.45^{S}
Neuromuscular variables					
Total impacts (n)	6796.40 ± 1396.81	6708.27 ± 1426.30	0.120	0.906	0.06^{S}
Total impacts (n/min)	96.82 ± 18.56	97.48 ± 19.97	-0.065	0.949	0.03^{S}
Impacts 0-3 g (n)	5818.80 ± 1221.36	5441.47 ± 1240.78	0.591	0.562	0.30^{S}
Impacts 0-3 g (n/min)	82.93 ± 16.49	79.05 ± 17.33	0.438	0.667	0.22^{S}
Impacts 3-5 g (n)	724.00 ± 348.38	881.20 ± 328.44	-0.914	0.373	0.46^{S}
Impacts 3-5 g (n/min)	10.31 ± 4.90	12.83 ± 4.77	-1.018	0.322	0.51^{M}
Impacts >5 g (n)	253.60 ± 293.27	385.60 ± 303.33	-0.849	0.407	0.43^{S}
Impacts >5 g (n/min)	3.59 ± 4.08	5.60 ± 4.43	-0.896	0.382	0.45^{S}
Player $Load_{RT}$ (UA)	48.45 ± 3.26	51.22 ± 10.71	-0.562	0.581	0.29^{S}
Player $Load_{RT}$ (UA/min)	0.69 ± 0.04	0.75 ± 0.15	-0.765	0.454	0.39^{S}

Note: *= significant difference; n= quantity: m= meters; m/min= meters per minute; km/h= kilometers per hour; g= magnitude of impacts in g-forces; AU= arbitrary units; AU/min= arbitrary units per minute.
Cohen's d effect size: ^{S}= small; ^{M} = moderate; ^{L}= large.

In the internal load variables shown in Table 2, no significant differences were found. Cardiac responses and energy expenditure are similar between men and women.

Table 2. Relative data of the internal load evaluated according to the sex of the referees.

Physiological variables	Women	Men	*t*	*p*	*d*
Heart rate maximal (bpm)	168.75 ± 13.72	171.15 ± 19.83	-0.224	0.826	0.13^{S}
Heart rate average(bpm)	142.75 ± 16.15	143.15 ± 17.81	-0.040	0.968	0.02^{S}
Zone 50-60% HRmax	12.00 ± 17.21	13.76 ± 24.40	-0.133	0.896	0.08^{S}
Zone 60-70% HRmax	30.84 ± 21.00	29.27 ± 24.29	0.116	0.909	0.07^{S}
Zone 70-80% HRmax	36.48 ± 21.63	34.88 ± 22.29	0.126	0.901	0.07^{S}
Zone 80-90% HRmax	18.91 ± 22.21	17.33 ± 21.39	0.128	0.900	0.07^{S}
Zone >90% HRmax	0.04 ± 0.10	2.55 ± 5.99	-0.918	0.371	0.47^{S}
Energy expenditure (kcal)	369.27 ± 30.79	373.42 ± 77.22	-0.115	0.909	0.06^{S}
Energy expenditure (kcal/min)	5.27 ± 0.39	5.44 ± 1.14	-0.321	0.752	0.17^{S}

Note: *= significant difference; bpm= beats per minute; HRmax= maximal heart rate; kcal= kilocalories; kcal/min= kilocalories per minute.
Cohen's d effect size: ^{S}= small; ^{M} = moderate; ^{L}= large.

Table 3 shows the data of the kinematic variables according to the period of the match. Significant differences are observed in the distances covered, reflecting a decrease in the values in the second times. Specifically, the total distance covered in meters per minute, the distances covered at 6-12 km/h, at 12-18 km/h (m/min) and >18 km / h, the average speed, the number of impacts in the categories 3-5 g and >5 g and the Player $Load_{RT}$ both total and per game minute showed a decrease.

Table 3. Absolute and relative data of the external load variables (kinematic and neuromuscular) evaluated by the referees according to the game periods.

Kinematic variables	First period	Second period	*t*	*p*	*d*
Total distance (m)	2277.78 ± 252.69	2288.76 ± 263.64	-.326	0.748	0.04^S
Total distance (m/min)	67.64 ± 8.86	64.08 ± 6.88	3.313	0.004*	0.40^S
Distance 0-6 km/h (m)	1042.25 ± 111.31	1101.90 ± 130.13	-2.093	0.050	0.54^M
Distance 0-6 km/h (m/min)	31.10 ± 3.36	31.03 ± 3.47	0.299	0.768	0.02^S
Distance 6-12 km/h (m)	755.83 ± 114.82	749.71 ± 153.19	2.663	0.015*	0.05^S
Distance 6-12 km/h (m/min)	22.62 ± 3.82	21.10 ± 4.20	0.828	0.418	0.40^S
Distance 12-18 km/h (m)	431.40 ± 114.14	395.73 ± 90.89	0.142	0.888	0.31^S
Distance 12-18 km/h (m/min)	12.95 ± 3.74	11.13 ± 2.52	2.135	0.046*	0.48^S
Distance >18 km/h (m)	48.29 ± 46.56	41.41 ± 28.47	3.514	0.002*	0.15^S
Distance >18 km/h (m/min)	1.46 ± 1.42	1.16 ± 0.79	1.178	0.253	0.21^S
Total accelerations (n)	636.05 ± 73.99	662.29 ± 92.15	-1.658	0.114	0.35^S
Total accelerations (m/min)	18.97 ± 2.11	18.63 ± 2.26	1.488	0.153	0.16^S
Total decelerations (n)	634.85 ± 73.59	662.88 ± 92.10	-1.835	0.082	0.38^S
Total decelerations (m/min)	18.93 ± 2.10	18.65 ± 2.28	1.341	0.196	0.14^S
Maximal speed (km/h)	19.56 ± 1.90	19.35 ± 1.68	1.673	0.111	0.11^S
Average speed (km/h)	4.87 ± 0.37	4.73 ± 0.35	2.741	0.013*	0.38^S
Neuromuscular variables					
Total impacts (n)	3412.00 ± 784.77	3318.30 ± 622.82	1.351	0.193	0.12^S
Total impacts (n/min)	101.79 ± 23.04	93.31 ± 16.39	1.259	0.223	0.37^S
Impacts 0-3 g (n)	2805.85 ± 694.02	2729.95 ± 541.25	0.600	0.555	0.11^S
Impacts 0-3 g (n/min)	83.66 ± 20.06	76.73 ± 14.22	0.977	0.341	0.35^S
Impacts 3-5 g (n)	424.75 ± 167.09	417.15 ± 169.23	3.426	0.003*	0.05^S
Impacts 3-5 g (n/min)	12.72 ± 5.07	11.76 ± 4.75	3.515	0.002*	0.19^S
Impacts >5 g (n)	181.40 ± 160.72	171.20 ± 141.17	2.139	0.046*	0.06^S
Impacts >5 g (n/min)	5.41 ± 4.85	5.11 ± 4.52	2.123	0.047*	0.06^S
Player $Load_{RT}$ (UA)	25.57 ± 5.28	24.96 ± 4.29	1.333	0.198	0.12^S
Player $Load_{RT}$ (UA/min)	0.76 ± 0.16	0.70 ± 0.12	2.902	0.009*	0.36^S

Note: *= significant difference; n= quantity: m= meters; m/min= meters per minute; km/h= kilometers per hour; g= magnitude of impacts in g-forces; AU= arbitrary units; AU/min= arbitrary units per minute.
Cohen's d effect size: ^{S}= small; ^{M} = moderate; ^{L}= large.

Table 4 shows that, of the internal load variables, only energy expenditure in kilocalories per minute presented a significant difference between the game periods, which was lower in the second half. Heart rates and percentages in work zones remain similar between both periods.

Table 4. Relative data of the internal load variables evaluated to the referees according to the game periods.

Physiological variables	First period	Second period	*t*	*p*	*d*
Heart rate maximal (bpm)	162.83 ± 29.51	161.78 ± 27.75	1.383	0.185	0.08^S
Heart rate average(bpm)	140.06 ± 24.57	138.06 ± 23.01	0.638	0.532	0.04^S
Zone 50-60% HRmax	12.52 ± 22.02	12.58 ± 22.40	-0.037	0.971	0.01^S
Zone 60-70% HRmax	26.26 ± 23.47	29.58 ± 24.06	-1.502	0.151	0.14^S
Zone 70-80% HRmax	31.75 ± 22.59	34.82 ± 24.14	-0.953	0.354	0.18^S
Zone 80-90% HRmax	18.86 ± 22.91	14.84 ± 20.93	1.193	0.249	0.20^S
Zone >90% HRmax	3.05 ± 8.86	1.28 ± 3.04	1.065	0.302	0.12^S
Energy expenditure (kcal)	189.93 ± 35.41	182.45 ± 34.82	1.829	0.083	0.21^S
Energy expenditure (kcal/min)	5.65 ± 1.18	5.11 ± 0.94	3.236	0.004*	0.46^S

Note: *= significant difference; bpm= beats per minute; HRmax= maximal heart rate; kcal= kilocalories; kcal/min= kilocalories per minute.
Cohen's d effect size: ^{S}= small; ^{M} = moderate; ^{L}= large.

Discussion

The purpose of this study was to analyses the external and internal load of the Costa Rican handball referees according to sex and game periods. To the best of the knowledge of the authors, this is the first work done in this topic in the Costa Rican context.

Comparing these data with those of previous research carried out on handball referees, it is necessary to consider the duration of each period and therefore of the game. The only work that provides data on distance traveled was obtained during a 40-minute game (García-Santos et al., 2017) and not 60 minutes as it was in this study. When comparing the distances covered, both total and covered at different intensity ranges in relation to playing time, it is observed lower with the data of Spanish referees directing cadet category matches (García-Santos et al., 2017). According to the percentage of meters per minute traveled at each speed range, the data of this study reflect that 46.95% was covered at an intensity of 0-6 km/h, 32.97% between 6-12 km/h, on 18.11 % between 12-18 km/h and only 1.96% at a speed greater than 18 km/h. In previous works it has been found that 94.5% of the distance was covered at an intensity lower than 7 km/h (García-Santos et al., 2017). Therefore, it may be mentioned that the Costa Rican referees traveled fewer meters per minute per game compared to that reported by Spanish referees (García-Santos et al., 2017), but Costa Ricans covered a greater percentage of distance at higher speeds compared to Europeans. Also, the dynamics with which each game was developed can be one of the causes of these differences. The intensity at which the players develop, as well as situational factors such as the demands of the match, the score, the playing tactics of the teams, among others, can have an influence on the external load of the referees (García-Santos et al., 2017; Rojas-Valverde et al., 2020). However, there are no studies on this line in handball referees.

Regarding the speed reached, the data obtained in this study reflect a maximum speed of 19.63 ± 1.85 and an average of 4.80 ± 0.34, which is higher than that reported in Brazilian referees (Fernandes da Silva et al., 2010) and Spanish (leading cadet category matches) (García-Santos et al., 2017). The accelerations and decelerations per minute of play found in this study are lower than those reported in handball referees (García-Santos et al., 2017), although comparing them with basketball referees they are superior (García-Santos et al., 2019). The number of impacts recorded and the Player Load$_{RT}$ in this study are higher in relation to what was reported in previous research with handball referees (García-Santos et al., 2017). This can be explained by the intensity of the movements performed during the game. The referees analyzed in this study covered a greater percentage of meters at high intensities, which increase the number of impacts.

The maximal and average heart rates of the referees analyzed agree with that found in Brazilian handball referees (Fernandes da Silva et al., 2010). Likewise, in this study, approximately 60% of the efforts were in a work zone lower than 80% of the maximal heart rate, while only 20% were higher than 80%, coinciding with what was reported in the literature, in the which is stated that the efforts of the handball referees are mostly of moderate intensity (Fernandes da Silva et al., 2010). In the literature, the above has been justified, mentioning that handball referees remain stopped or walking during positional attacks, while in attack-defense or defense-attack transitions the intensity of the efforts increases (García-Santos et al., 2017). When comparing these percentages with those reported in referees of other sports, similarities are observed during U16 basketball matches, in which the referees spent around 83% of the playing time at an intensity between 50-80% of HRmax, and only 3.2% higher than 80% of HRmax (García-Santos et al., 2019). Compared to futsal referees, the percentages differ a little, they performed around 12% of the time efforts less than 70%, 78% between 70-90% and 10% above 90% of HRmax. (Rebelo et al., 2011).

The scientific works that establish comparisons of the external and internal load according to the sex of the referees are very scarce (García-Santos et al., 2020). No studies have been found that have compared kinematic profiles of male and female referees and few studies have included female referees in their analyzes (García-Santos et al., 2020; Vaquera et al., 2016). The results obtained in this work only indicate significant differences in the distance traveled at the speed of 0-6 km/h. Although no significant differences were found in the present study according to sex, a study carried out by Vaquera et al. (2016) found lower heart rates in female basketball referees compared to men, and the percentage of time spent in a zone> 70% of HRmax was higher in men, which is associated with physical behaviors during the game (Vaquera et al., 2016).

Regarding the differences found between the first and second period in variables such as: the total distance traveled, the distance traveled at 6-12 km/h, at 12-18 km/h (m/min) and >18 km/h, the average speed, the amount of impacts in the categories 3-5 g and >5 g and the Player Load$_{RT}$, this study is one of the first studies that analyzes it, so we did not find previous research to contrast it in handball. In other sports, such as basketball, it has been described that the periods affect the kinematic variables (Rojas-Valverde et al., 2020). The observed behavior of the kinematic variables shows a tendency to decrease in the second periods, coinciding with that reported in futsal referees, where a shorter distance traveled has been observed in the second periods (Ahmed et al., 2017). Similarly, the Player Load$_{RT}$ decreased in the second half. In basketball matches, the referees have shown a decrease in this indicator, expressed both in absolute and relative terms (García-Santos et al., 2019). This may be explained by the demands of the game, the physical effort of the first half accumulates and can cause alterations in neuromuscular, cardiovascular and metabolic functions that provide the appearance of fatigue, affecting physical performance in the second periods (Ali Nabli et al., 2017; Castillo et al., 2016; Mallo et al., 2006).

The only physiological variable that showed a significant difference in the second period of play was energy expenditure. The average values were 189.93 ± 35.41 kcal (5.65 kcal/min) and 182.45 ± 34.82 kcal (5.11 kcal/min) for the first and second period respectively and for the complete game it was 372 kcal (5.39 kcal/min). In a study carried out with basketball referees who directed U19 matches, they report an average energy expenditure of 504.4 ± 77.7 during the game, and indicate that in the last quarter there was an increase in energy expenditure in relation to the previous three quarters (Ali Nabli et al., 2017), which differs from the results of this study, where it was found that energy expenditure decreased in the second period.

Conclusions

Sex does not seem to affect external or internal load. Between men and women, a statistically significant difference was only shown in the distance traveled at a speed between 0-6 km/h, presenting higher values in men. There were no differences between men and women in physiological demands. This work provides important information in this regard and may be a starting point for further research in this line.

The game periods seem to influence the external load but not so much the internal load. In the second half the distances covered, the average speed, the number of impacts in the 3-5 g and> 5 g categories and the Player Load$_{RT}$ are lower compared to the first half. Cardiovascular demands remain similar in both periods, only energy expenditure in kilocalories per minute showed a significant decrease.

Information on previous studies analyzing internal and external loads on handball referees is almost non-existent. The only two studies found (Fernandes da Silva et al., 2010; García-Santos et al., 2017) were prepared with different methodologies and with different populations, so a broad comparison is not feasible to locate the results of these investigations with respect to the present one. Hence the importance of continuing in this line of research to expand the existing data and to be able to make improvements in referee preparation based on the results obtained.

Practical applications

The results found in this study describe the physical and physiological efforts presented by the referees when refereeing U19 matches according to the game and gender. These data can be considered to program training sessions that adjust to the demands faced in the competition, to develop specific physical tests for the handball referee, or to prevent sports injuries. Also, this study can be a starting point for considering other investigations that address this type of analysis in mayor categories and with international referees.

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