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ORIGINAL

INFLUENCE OF GAME PERIOD AND GAME ACTION IN THE PHYSICAL REQUIREMENTS OF BASKETBALL REFEREES

INFLUENCIA DEL PERIODO Y ACCIÓN DE JUEGO EN LAS EXIGENCIAS FÍSICAS DE ÁRBITROS DE BALONCESTO

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ABSTRACT

This study aimed to identify internal and external workload demands in professional referees, and to analyse the influence of the situational variables *Game Period* and *Game Action*. Three professional referees of the highest category were monitored during a national elite game. WIMU PRO™ inertial devices were used for workload monitoring via microtechnology, ultra-wide band and heart rate (HR) telemetry. The referees worked at around 82%HR_{MAX} and spent 75% of the time at walking-jogging speed (0-12km/h). *Game Action* influenced the external workload (total distance and per intensities, impacts, player load, maximum and mean speed) while *Game Period* influenced the internal load (HR_{MEAN}, HR_{MAX}, %HR_{MAX} and per intensities). Workload quantification in competition and the evaluation of the effect of situational variables are essential for setting up performance profiles and designing individual programmes that improve the training of basketball referees.

KEYWORDS: Physical demands, inertial devices, competition, referees, basketball.

RESUMEN

Los objetivos del estudio fueron identificar las demandas de carga interna y externa en árbitros profesionales, y estudiar la influencia de las variables situacionales *Periodo* y *Acción de juego*. Tres árbitros profesionales de máxima categoría fueron monitorizados durante un partido de élite nacional. Dispositivos inerciales WIMUPRO™ fueron empleados para monitorizar las exigencias mediante microtecnología, radiofrecuencia de ultra-banda ancha y frecuencia cardiaca (FC). Los árbitros trabajaron al 82%FC_{MAX} y se desplazaron un 75% del tiempo andando-trotando (0-12km/h). La *Acción de juego* influyó en la carga externa (Distancia total y por velocidades, impactos, PlayerLoad, velocidad media y máxima) mientras que el *Periodo de juego* afectó a la carga interna (FC_{MAX}, FC_{MEDIA}, %FC_{MAX} y por intensidades). La cuantificación de las demandas en competición y evaluar el efecto de las variables situacionales es fundamental para generar perfiles de rendimiento y diseñar programas individuales que mejoren el entrenamiento en árbitros de baloncesto.

PALABRAS CLAVE: Demandas físicas, dispositivos inerciales, competición, árbitros, baloncesto.

1. INTRODUCTION

Basketball is a cooperation-opposition sport played by two teams of 5 players each, with the aim of throwing the ball into the opponents' basket, and preventing them from throwing it into one's own basket; and is one of the most practised sports worldwide. Basketball rules have evolved since its origins in order to positively improve its development (Ibáñez, García-Rubio, Gómez & González-Espinosa, 2018). One of the agents that participate in the game are the referees. Their intervention is fundamental for the development of the match, as they are charged with making sure that the rules are complied with. The figure of the referee is essential at all levels of competition (García-Santos & Ibáñez, 2016), and their intervention is progressive at all the formative stages and competitive levels (Vizcaíno, Saénz-López & Rebollo, 2016), because as the competitive level increases there is a need for a stricter application of the rules and a higher level of physical fitness (García-Santos, Gómez-Ruano, Vaquera & Ibáñez, 2020a). Mitjana (2009) indicates that the basketball referee must have: (a) the ability to coordinate knowledge about the game, the rules and that derived from experience; (b) knowledge of location of actions and nonverbal communication; (C) capacities like visual acuity and good physical fitness; and (d) the necessary psychological or communication resources to be able to control the match. The body of referees, like the other protagonists of the game, require complete training (González, 2005) and the ability to manage stress during the competition (García-Santos, Vaquera, Calleja-González, González-Espinosa & Ibáñez, 2017b).

The technique of refereeing changes according to the number of referees that intervene during a match. Currently, there are competitions with different numbers of referees. It is worth mentioning that in formative categories the refereeing is performed by two referees, whose movements are very different from those that are seen in FIBA referees where there are three. In this case the responsibilities are distributed according to where the strong and weak sides of the game occur (García-Santos et al., 2020a). Trail and lead referees are charged with controlling the strong side of the game while the centre referee is responsible for controlling the weak side. Leicht, Connor, Conduit, Vaquera & Gómez (2020) highlight in their investigation that refereeing with three referees reduces their movement, exercise intensity and physical and psychological fatigue, which will make them better disposed to making decisions (ÇIÇEK et al., 2021).

In the sports context, investigations and studies are mainly focused on players and coaches, and there are few that fix their attention on referees (García-Santos & Ibáñez, 2016). Thus, it is necessary to do research on this group to characterise the refereeing context (Guillén & Jiménez, 2000). García-Santos et al. (2020a) indicate that basketball referees have to work to improve three main aspects: decision making, physical/psychological condition and situations of stress. Specifically, basketball referees are faced with a constantly changing environment in which (Sivakumaran et al., 2018), due to the limitations of time within which they have to perform their function, their ability to rapidly and accurately perceive game events, is essential for skilled refereeing (Mitjana, 2009). Therefore, the capacity of the referee to respond to the physical and physiological demands is key for refereeing many sports, especially basketball (García-Santos et al., 2020a).

One of the most commonly used physiological variables for quantifying the internal load of referees in invasion sports has been heart rate, as it is easily recorded with different portable devices. Several examples can be found for basketball (García-

Santos, Pino-Ortega, García-Rubio, Vaquera & Ibáñez, 2019a; García-Santos, Pino-Ortega, García-Rubio, Vaquera & Ibáñez, 2020b; Vaquera, Mielgo-Ayuso, Calleja-González & Leicht, 2016a; Montgomery & Maloney, 2018), football (Gómez-Carmona & Pino-Ortega, 2016), futsal (Ahmed, Davison & Dixon, 2017), or handball (García-Santos, Gamonales, León, Mancha-Triguero & Muñoz, 2017a).

Other studies have used different parameters derived from the external demands of kinematic and neuromuscular effort, like distance covered, speed, accelerations or player load in different invasion sports like football (Ahmed et al., 2017; Gómez-Carmona & Pino-Ortega, 2016), basketball (García-Santos et al., 2019b; García-Santos et al., 2019a; Leicht et al., 2019; Rojas-Valverde, Gómez-Carmona, Oliva-Lozano, Ibáñez & Pino-Ortega, 2020), and handball (García-Santos et al., 2017a). All these parameters provide additional information on multiple variables like fitness level, the type of competition, the number of referees in the match, the gender of the competitors or the characteristics of the match (Nabli et al., 2019).

As mentioned, the research carried out in the field of internal and external load in basketball referees has mainly focused on characterising the demands in total (García-Santos et al., 2020a) and analysing the interaction between the internal and external load variables (García-Santos et al., 2020b), but not taking into account the effect of the situational variables that have been shown to directly influence external load like the game situation (González-Espinosa, García-Rubio, Feu & Ibáñez, 2020). Performance will also be modified by intrinsic factors to the game dynamics like match period (Rojas-Valverde et al., 2020), as well as the different specific game actions like transitions, positional attacks or situations in which the ball is dead and play stopped. As far as we are aware there are no investigations which analyse the internal and external load supported by a referee during competition according to the game action. Thus, the objectives of the present study were: (a) to describe and characterise the internal and external load of the basketball referee during the competition, and (b) to identify the influence of the contextual variables match period and game action.

2. METHOD

2.1. Design and participants

The present study follows a cross-sectional design with natural groups with the aim of ascertaining the internal and external load demands of professional referees during a pre-season match in the highest official Spanish basketball competition, the Endesa League of the Association of Basketball Clubs (ACB) (Ato, López & Benavente, 2013). To this end, three referees from the highest national category (group 1) were monitored; they had a mean age of 34 years, experience of 9±8 seasons in the Endesa League and 18±11 years refereeing. The refereeing teams are composed of a senior referee, an experienced referee and a novice referee, which explains the high standard deviation found. The referees and the clubs were informed at the beginning of the study of the whole experimental procedure, and signed a written informed consent form. The present study was carried out following the ethical stipulations of the Declaration of Helsinki and was approved by the University Bioethics committee (registration nº 67/2017).

2.2. Sample

A total of 332 actions were selected from the four periods of a complete game, and checked by several experts for their categorisation. The distribution of the actions per game period was as follows: 75 actions in the first period, 88 actions in the second period, 84 actions in the third period and 85 actions in the fourth period. There was a total of 137 positional attack actions, 141 transition actions, 20 dead ball actions without change of possession, 18 dead ball actions with change of possession and 16 free throw actions.

2.3. Study variables

The independent study variables were the situational variables *Game period* and *Game action*. The study dependent variables were grouped into internal load variables and external load variables.

Independent variables

- *Game period*. A basketball match comprises four periods of 10 minutes each called: 1st quarter, 2nd quarter, 3rd quarter and 4th quarter.
- *Game action.* The following situations were considered, established and agreed upon by a committee of experts composed of 4 referees from the highest category (group 1): *Positional (P)*, when the rival defence was correctly positioned to avoid the easy and rapid approach of both the ball and the players to the basket; *Transition (T)*, when there was no organisation either of attack or defence in the approach to the rival basket, *Dead ball with change of possession (DBC)*, when the live ball became dead with change of possession; *Dead ball without change of possession (DBW)*, when the live ball became dead although the same team maintained possession; and *Dead ball with free throw (DBFT)*, when the live ball became dead because of a team foul penalised with free throws.

Dependent variables of internal load

- *Maximum Heart Rate* (HR_{MAX}): Maximum number of beats per minute recorded in the competition.
- *Mean heart rate* (HR_{MEAN}): Mean number of beats per minute recorded in the competition.
- *Percentage of maximum heart rate* ($\%HR_{MAX}$): Relation between the mean heart rate recorded and the maximum heart rate achieved in the competition, expressed in percentage.

- *Heart rate zones*. Following the proposal of Vaquera, Mielgo-Ayuso, Calleja-González & Leicht (2017) six categories were established: (a) Z1 (50-60% HR_{MAX}); (b) Z2 (60-70% HR_{MAX}); (c) Z3 (70-80% HR_{MAX}); (d) Z4 (80-90% HR_{MAX}); (e) Z5 (90-95% HR_{MAX}); (f) Z6 (>95% HR_{MAX}). The maximum heart rate of each referee was determined according to the formula proposed by Whaley, Kaminsky, Dwyer, Getchell & Norton (1992) for men:

  *HRMax (bpm)= 203.9 – [0.812*Age] + [0.276*HRBasal] – [0.084* Body Mass Index (BMI)]*

Dependent variables of external load

- *Accelerations* (*Acc*): Total number of positive speed changes developed during the match.
- *Decelerations* (*Dec*): Total number of negative speed changes developed during the match.
- *Distance covered* (*Distance*): Total of the distances covered by the referees expressed in metres.
- *Maximum speed* (S_{MAX}): Maximum speed achieved during the match.
- *Mean speed* (S_{MEAN}): Average speed of locomotion during the match.
- *Speed zones*: The default categories of the software manufacturer were used to establish the criteria for the speed zones: (a) S1, walking (0-6 km/h); (b) S2, jogging (6-12 km/h); (c) S3, running (12-18 km/h); (d) S4, running (>18 km/h).
- *Impacts:* This was calculated from the G forces experience by each referee during the different game situations (Puente, Abián-Vicén, Areces, López & Del Coso, 2017). The total value is the sum of the impacts produced when the vectorial sum of the G forces exerted in the three planes of movement (x, y, z) is higher than 2 G.
- *Player load* (*PL*): This is the measurement derived from the accelerometer of the total body load in its 3 axes (vertical, anterior-posterior and medio-lateral). This variable is used to assess the neuromuscular load in different athletes. It is represented in arbitrary units (a.u.) and is calculated using the following equation where PLn is the PL calculated in the present instant; n is the present instant in time; n-1 is the previous instant in time; Xn, Yn and Zn are the value for body load in each axis of movement at the present instant of time; and Xn-1, Yn-1 and Zn-1 are the values for body load in each axis of movement at the previous instant (Gómez-Carmona, Bastida-Castillo, Ibáñez & Pino-Ortega, 2020):

$$PL_n = \sqrt{\frac{(X_n - X_{n-1})^2 + (Y_n - Y_{n-1})^2 + (Z_n - Z_{n-1})^2}{100}}$$

$$Accumulated\ PL = \sum_{n=0}^{m} PL_n\ x\ \ 0{,}01$$

2.4. Instruments

The variables of external load were recorded with an inertial device called a WIMU PRO™ (RealTrack Systems, Almería, Spain), located in an anatomical harness on the interscapular area of the referee. This device is composed of different sensors for detecting movement such as microelectromechanical sensors (four accelerometers, three gyroscopes and a magnetometer) with an adjustable sampling frequency of between 10 and 1000 Hz, dual localisation sensors using satellite global navigation systems at 10 Hz and ultra-wide band (UWB) at 20 Hz for indoor conditions, as well as wireless communication technologies to link other sensors like Wi-Fi, Bluetooth and Ant+. To record internal load, each referee was equipped with a GARMIN™ heart rate band, which sent the recording to the inertial device at a sampling frequency of 4 Hz using Ant+ technology.

UWB positioning technology was used for the positional analysis in indoor conditions. To install the system, antennas have to be located in the sports area to simulate the constellation of satellites outside, and form a field of reference using radio frequencies to determine the position of each referee or player. Its use is relatively recent for monitoring referees (García-Santos et al., 2019a; Rojas-Valverde et al. 2020), and has obtained satisfactory values for validity and reliability both in basketball (Pino-Ortega, Bastida-Castillo, Gómez-Carmona & Rico-González, 2020) and handball (Bastida-Castillo, Gómez-Carmona, Hernández-Belmonte & Pino-Ortega, 2018). In the present study, 8 antennas were placed outside the court at 2.5 metres from the corners and 4 metres behind the baskets, as well as on the midline of the playing area. These antennas were placed on the outside of the court forming an octagon for a better signal for emission and reception (Figure 1).

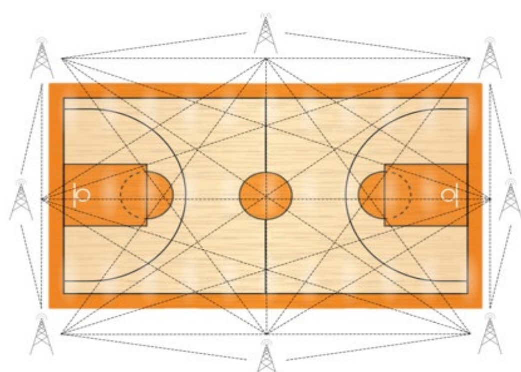

Figure 1. *Configuration of the system of antennas in the play area*

2.5. Procedure

The data collection took place during a pre-season match between two professional basketball teams from the Endesa League (ACB), held on 26th August 2020 at 19:15h in the San Pablo Municipal Sports Stadium in Seville. The final result was 74-90 (1Q: 22-20, 2Q: 18-29, 3Q: 17-16, 4Q: 17-25). The UWB indoor positioning system was installed 75 minutes before the start of the match by placing the antennas around the court. Subsequently, and before the beginning of the warm-up, each referee was equipped with the GARMIN™ heart rate band and the WIMU PRO™ inertial device. During the match, time marks were made for the game periods and game actions using SVIVO™ software to provide indications corresponding to the previously determined different situational variables. In this way marks were made to differentiate among game periods and game actions.

At the end of the match, the inertial devices were collected from each of the referees and their data were downloaded. The files from the inertial devices and the time marks from the SVIVO™ software were imported into the SPRO™ software for the analysis of the variables of internal and external load included in the study. The time marks recorded (*Game periods* and *Game actions*) were reviewed and adjusted using the synchronisation of the video of the match in the SPRO™ software. After the adjustment of the time marks, the data were exported into a Microsoft Excel program where they were organised and the database created. Finally, the data were imported into SPSS for their statistical analysis.

2.6. Data analysis

First, an exploratory analysis was carried out through the statistical testing of assumptions. Tests were conducted to confirm the normality, randomness and homoscedasticity of the data to establish the adequate model to confirm the hypothesis (Field, 2013). All the variables presented a normal distribution, except those of mean and maximum speed which showed a non-normal distribution. The actions of *Time Out* and the breaks between periods and at the half-way stage were deleted from the analysis of the load, as it was considered that they could contaminate the results of the sample as they were not specific game actions.

Subsequently a descriptive analysis of the data was made using mean and standard deviation. A one-way ANOVA was used to determine the differences in the work load between the different game periods and the different game actions. F was analysed to determine this variance, as well as the observed level of significance (p) and the effect size using partial omega squared (ω_p^2). This was interpreted as: insignificant ω_p^2<0.01; low ω_p^2<0.06; moderate ω_p^2<0.14; and high ω_p^2>0.14 (Kirk, 1996). The post-hoc differences were analysed using Bonferroni (equality of variances) in all the variables analysed except average and maximum speed where the Games-Howell test (inequality of variances) was used. The statistical analysis was performed with SPSS 25 (IBM Corp. Released 2017. IBM SPSS Statistics para Windows, Version 25.0. (Armonk, NY, USA: IBM Corp.). The graphics were designed with GraphPad Prism, Version 7.0 (La Jolla, CA, USA, GraphPad Software). The level of significance was set at p<.05.

3. RESULTS

3.1. Game period

Figure 2 presents the descriptive and inferential results of the variables of internal load in relation to *Game period*. It can be seen that the referees in the study worked at 82%HR_{MAX} ($\overline{X}$=82.47; *SD*=2.42), with a HR_{MAX} of around 160 beats per minute (bpm) ($\overline{X}$=160.67; *SD*=7.95) and a HR_{MEAN} de 136 bpm ($\overline{X}$=136.39; *SD*=7.37). Moreover, the subjects spent about 82% of the match between 70-90%HR_{MAX}.

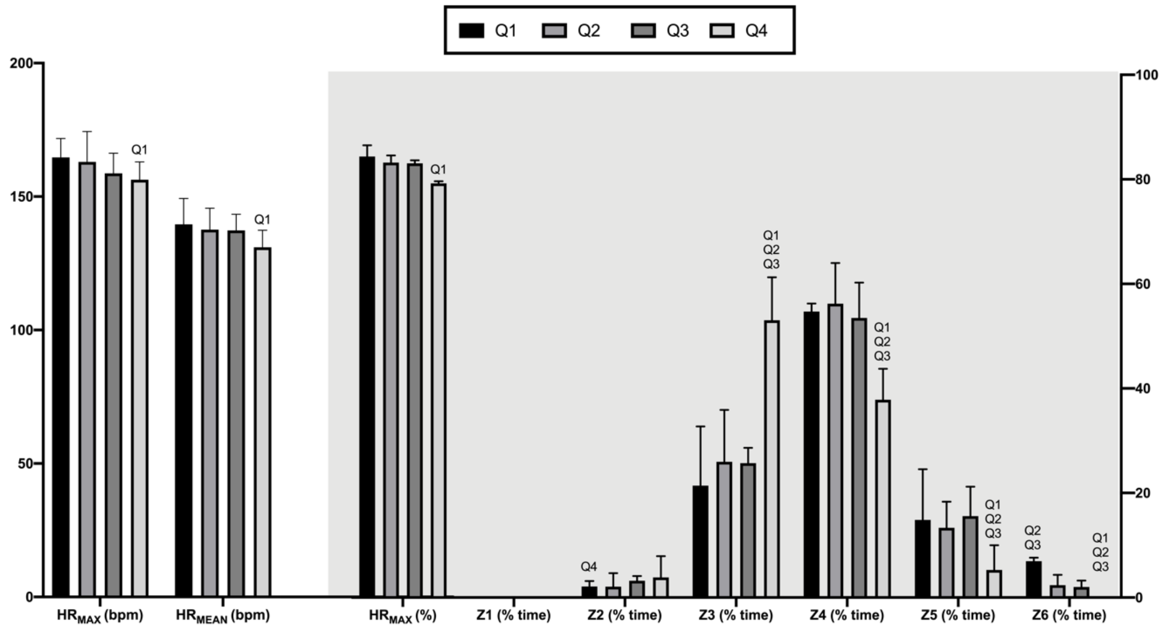

Figure 2. Graph of the variables of internal load according to game period.
Significant differences (p<.05) with the Q1first, Q2second, Q3third, and Q4fourth period.
Variables in the white shaded area refer to the left y axis and in the grey shaded area to the right y axis.

Regarding the influence of the game period, significant differences were identified in all the variables (p<.05; HR_{MEAN}, F=24.34, ω_p^2=0.17 *high*; HR_{MAX}, F=21.07, ω_p^2=0.15 *high*; %HR_{MAX}, F=22.23, ω_p^2=0.16 *high*; Z2, F=5.93, ω_p^2=0.04 *low*; Z3, F=33.44, ω_p^2=0.22 *high*; Z4, F=9.58, ω_p^2=0.07 *moderate*; Z5, F=6.60, ω_p^2=0.05 *low*; Z6, F=8.80, ω_p^2=0.06 *moderate*), except in the heart rate zones Z1 (p=1.00; F=0.00; ω_p^2<0.01 *insignificant*). Specifically, these differences were found in all the variables analysed between the first and fourth quarters (p<.05; Q1 vs Q4; HR_{MAX}: 165 vs 156 bpm; HR_{MEAN}: 140 vs 130 bpm; %HR_{MAX}: 85 vs 79%; Z2: 2 vs 4%; Z3: 21 vs 53%; Z4: 55 vs 37%; Z5: 15 vs 5%), except in the Z6 heart rate zone in which significant differences were found in all the periods (Q1=6.9; Q2=2.4; Q3=2.03; Q4=0).

Figure 3 shows the results for kinematic external load according to the game period, where it can be seen that the referees in the study covered a mean distance of 4032.6±52.1 metres, and performed approximately a total of 2300 accelerations (2304.7±209.1), and 2300 decelerations (2307.3±208.9), achieving a S_{MAX} of 27.1 km/h, with a S_{MEAN} of 5.2±0.2 km/h. All of which led to 5377.3±148.6 impacts and a total player load of 36.3±0.8 a.u.

With regard to the effect of the game period on the variables of external load, significant differences were only identified in the following variables S_{MAX} (p=0.01; F=3.63; ω_p^2=0.02 *low*), and S4 (p=0.01; F=3.03; ω_p^2=0.02 *low*). The Games-Howell pairwise comparison identified differences between the first, second and third periods compared to the fourth (Q1=Q2=Q3>Q4; 22.1, 24.5 and 22.8 vs 20.0 km/h, respectively) in S_{MAX} and using Bonferroni's test in V4 between the third and fourth periods (Q3>Q4; 61.8 vs 17.9 metres).

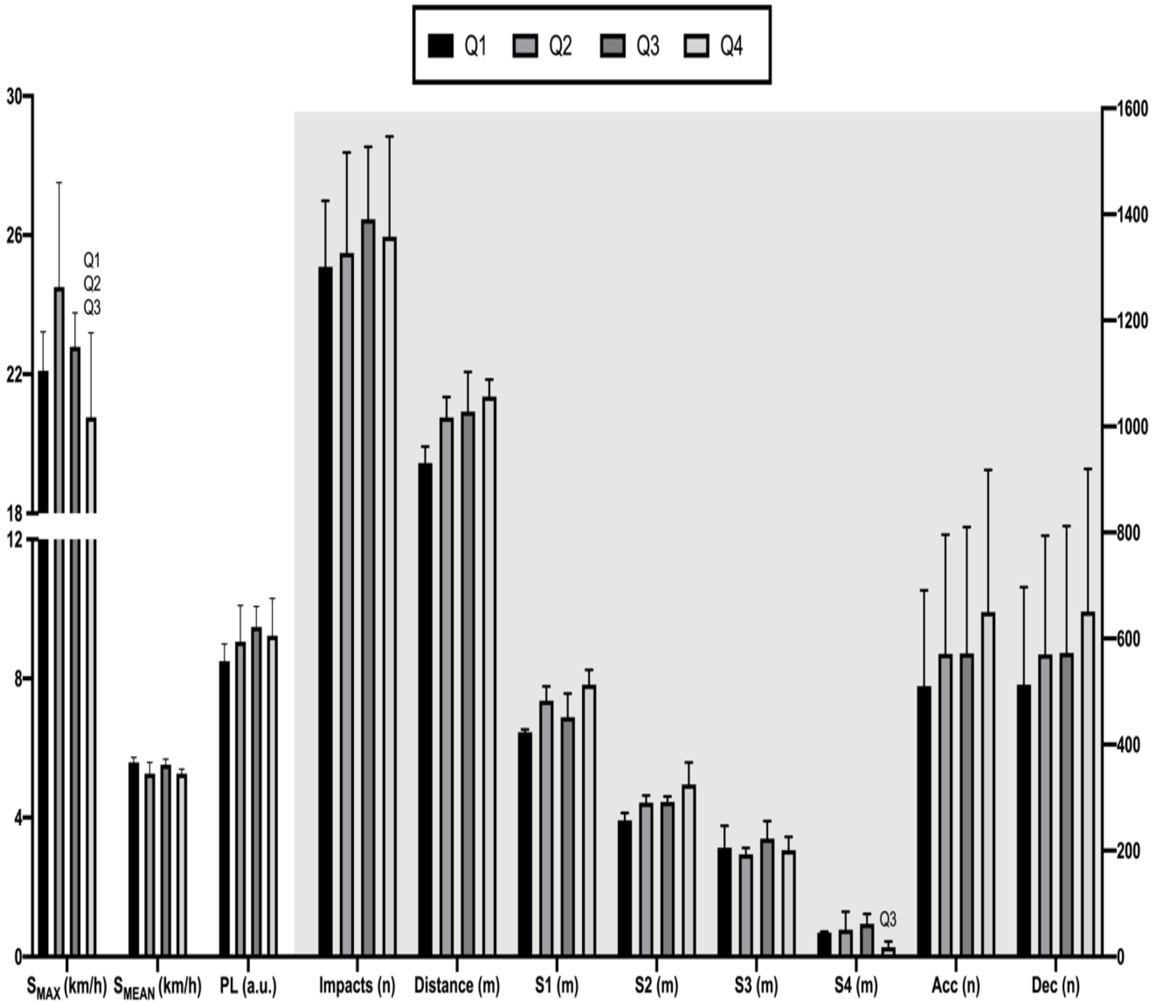

Figure 3. Graph of the variables of external load according to game period.
Significant differences (p<.05) with the [Q1]first, [Q2]second, [Q3]third, and [Q4]fourth period.
Variables in the white shaded area refer to the left y axis and in the grey shaded area to the right y axis.

3.2. Game action

Figure 4 shows the descriptive and inferential results for internal load according to game action (range of mean values; HR_{MAX}= 164.7 to 157.0 bpm; HR_{MEAN}= 136.7 to 131.8 bpm; $\%HR_{MAX}$= 82.7 to 79.5%; Z1= 0%; Z2= 6.03 to 2.00%; Z3= 44.5 to 27.7%; Z4= 59.0 to 42.72%; Z5= 13.4 to 5.7%; Z6= 5.3 to 0.9%). No significant differences were found in the variables of internal load analysed (p>.10; F< 1.93; w_p^2<0.01 *insignificant*), except in %HRMAX (p=.02; F=4.48; ω_p^2<0.03 *low*) with higher values in transition actions compared to free throw actions (82.7 vs 79.5%).

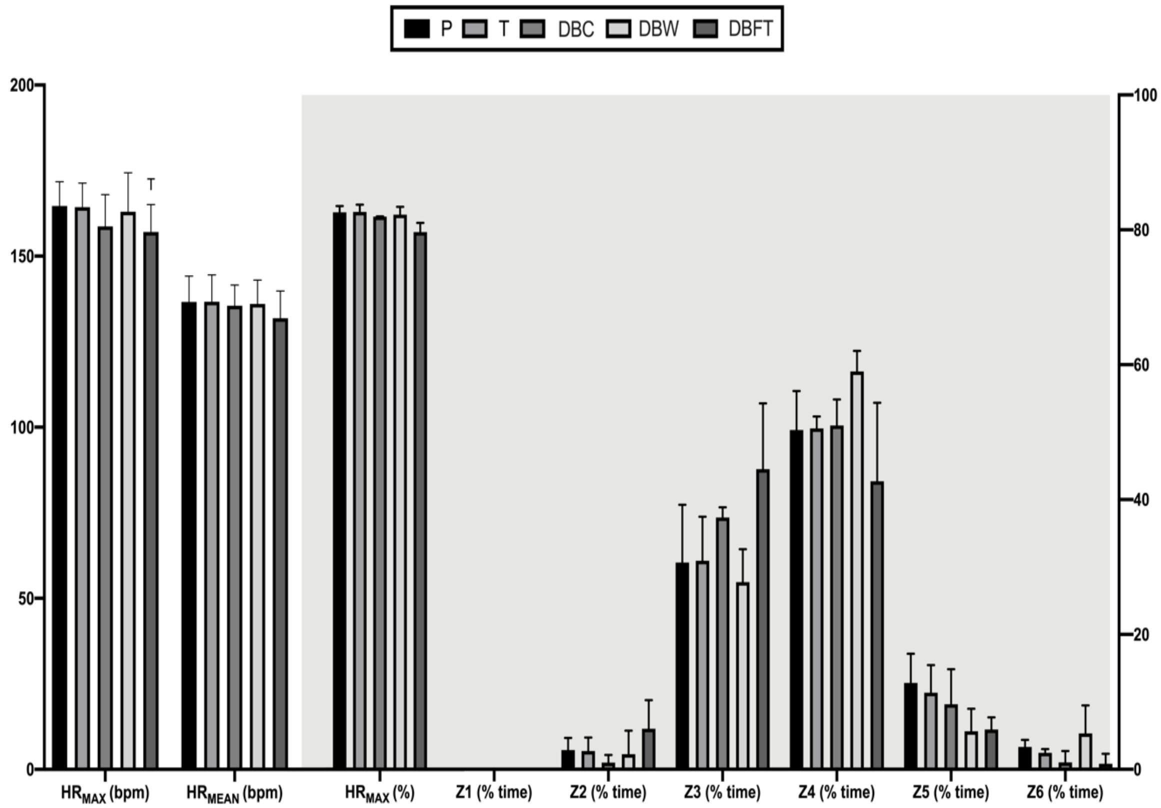

Figure 4. Graph of the variables of internal load according to game action.
Significant differences (p<.05) with [P]Positional, [T]Transition, [DBC]Dead ball with change of possession, [DBW]Dead ball without change of possession, and [DBFT]Dead ball with free throw.
Variables in the white shaded area refer to the left y axis and in the grey shaded area to the right y axis.

Finally, Figure 5 shows the descriptive and inferential results of kinematic external load according to game action. Statistically significant differences were found in all the variables analysed (p<.01; F> 23.01; ω_p^2>0.17 *high*). Specifically, significant differences were found for Distance, SMAX, SMEAN, in the S2 and S3 speed zones, as well as in impacts and player load with higher values in the transition actions (T > P > DBW = DBC = DBFT; Distance: 2204, 949, 267, 246 and 364 metres; SMAX: 22.9, 16.2, 10.8, 16.3 and 13.5 km/h; SMEAN: 8.4, 3.2, 3.5, 3.1 and 2.9 km/h; S2: 837, 187, 55, 50 and 36 metres; S3: 786, 22, 1, 6 and 6 metres; Impacts: 3286, 1410, 216, 217 and 247 impacts; player load: 23.3, 7.4, 1.6, 1.7 and 2.3 a.u.). In contrast, significant differences were found in the variables of Accelerations, Decelerations and the S1 speed zone with higher values in the positional game actions (P > T > DBW = DBC = DBFT; Accelerations: 832, 532, 246, 269 and 325 accelerations; Decelerations: 878, 480, 248, 273, and 327 decelerations; S1: 741, 408, 212, 188 and 222 metres). Significant differences were also found in the S4 speed zone with higher values in transition (T > P = DBW = DBC = DBFT; 173 vs 0 metres). No differences were found between actions of dead ball without change of possession, dead ball with change of possession, and dead ball with free throw actions.

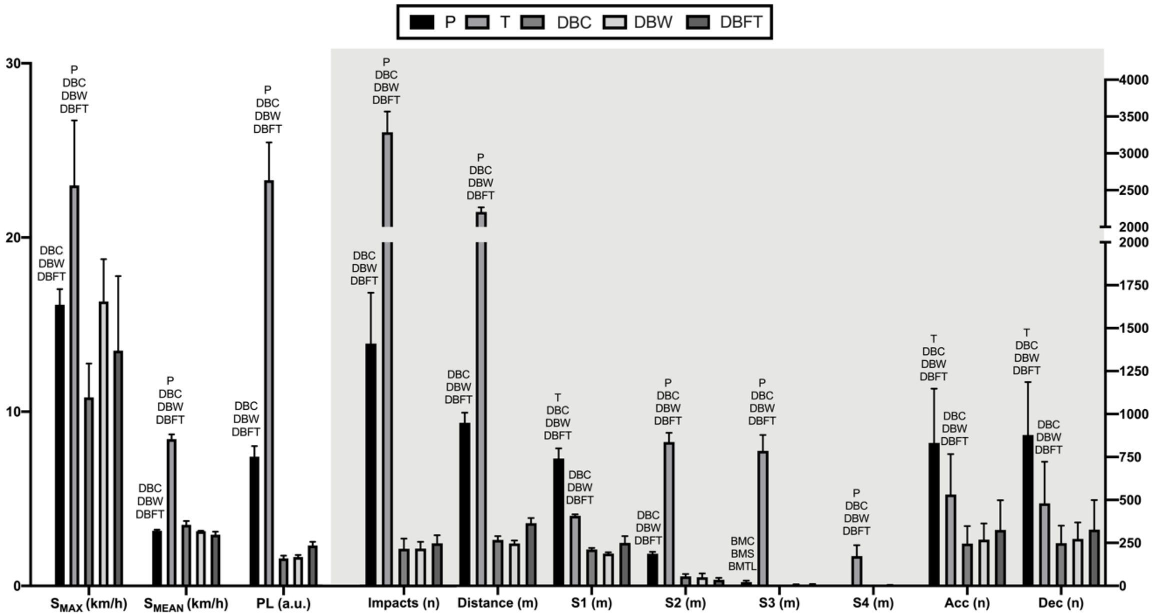

Figure 5. Graph of the variables of external load according to game action.
Significant differences (p<.05) with [P]Positional, [T]Transition, [DBC]Dead ball with change of possession, [DBW]Dead ball without change of possession, and [DBFT]Dead ball with free throw.
Variables in the white shaded area refer to the left y axis and in the grey shaded area to the right y axis.

4. DISCUSSION

The general objective of this research was to study the load supported by basketball referees in a real competitive situation, and it was found that there are significant differences in the internal load according to the game period and in the external load according to the game action. It is very important to analyse the work load of basketball referees and players in order to ascertain the different factors that intervene, as well as to be able to establish different guidelines for planning their training (García-Santos et al., 2020a; Rojas-Valverde et al., 2020).

HR has traditionally been the main indicator used to assess physical performance in athletes and referees in the sports context (Reina, García-Rubio, Antúnez & Ibáñez, 2020; Vaquera et al., 2016a; Vaquera, Mielgo-Ayuso, Calleja-González & Leicht, 2016b; García-Santos et al., 2020a). In the present study, the percentage of HRmax was higher than 82%. Previous research has shown levels of similar intensity in professional referees (Vaquera et al., 2016a; Matković, Rupčić & Knjaz, 2014). In contrast, referees from lower categories show much lower values (60-70% HR_{MAX}) (García-Santos, Pino-Ortega et al., 2019a). The demands experienced by the referees are similar to those recorded by professional players during the competition (Leich et al., 2019). Thus, it is necessary to specialise the physical training of referees according to the competitive level, as well as to try to achieve their optimal physical fitness that is equal to or higher than that of the players, which will lead to their being better positioned and less fatigued and capable of making optimal decisions.

With regard to the evolution of heart rate during the match, lower values were recorded in the last period. The scientific literature reports both increasing values throughout the match with a higher load in the last quarter (Vaquera et al., 2017), and lower values in the last quarter compared to the rest of the periods (García-Santos et al., 2019a). Thus, this disparity in results could indicate that the dynamic of the internal load of the basketball referee in competition could be explained by two factors: (1) the game dynamic, where the difference in points on the scoreboard between quarters in close and balanced matches affected the demands, whereas no significant differences were found in unbalanced games (Rojas-Valverde et al., 2020), and a greater variability in the first periods due to the teams seeking to impose their pace from the beginning and a lower variability in the last periods due to the high number of interruptions experienced (García-Rubio, Gómez, Cañadas & Ibáñez, 2015); and (2) the increase in fatigue both of the referees and the players, as the external and internal load supported by referees and players during the game is interrelated (García-Santos et al., 2020b; Vaquera et al. 2016b). Other factors that could affect the internal load are the category of the competition, the gender of the players and the mechanics of refereeing (García-Santos et al., 2019a; García-Santos et al. 2017b; Vaquera et al., 2016a). It is therefore necessary to design comprehensive training for referees considering the internal and external factors that can influence their physiological response during competition.

Similarly, the external load supported by the basketball referee is a parameter that should be accurately assessed according to the level of competition to be able to adjust their preparation to diverse competitive scenarios (García-Santos et al., 2020a). The referees studied covered a total of 4032 metres on average, demands similar to those previously recorded in professional basketball referees (García-Santos et al., 2019b; Nabli et al., 2016, 2019; Leicht et al., 2019). However, the distance covered is an insufficient indicator for measuring the physical demands of a basketball referee, because most of their movement corresponds to walking or jogging (Nabli et al., 2016), accounting for more than 75% of the match (between 0-12 km/h). The specific training of a referee should at least include a continuous effort over the distance that can be covered in a match, at different intensities.

For this reason, it is necessary to identify other indicators like the maximum demands recorded using maximum speed reached, higher than 27 km/h in the present study, which is greater than that recorded by referees in the formative categories (García-Santos et al., 2019a). In this respect, a higher level of players requires the referees to reach the end of the opponent's court as quickly as possible to be standing still and in ideal conditions to correctly make technical decisions during the competition, which implies getting to the end position before the players. Sprinting at maximum intensity and over distances similar to those of a basketball court should figure in the referees' physical training.

Regarding the number of accelerations and decelerations, it is noteworthy that this is an important aspect, especially in intermittent sports, as it will partially determine the referee's performance during the match and the decisions made (Delaney, Cummins, Thornton & Duthie, 2018). The results of the study place the number of both accelerations and decelerations in the match at around 2300, a smaller number than that recorded in formative categories (García-Santos et al., 2019b). This aspect could be explained due to the dynamic of professional basketball that is characterised by longer possessions and less transitions than in formative basketball (Conte et al., 2018; García-Rubio, Ibáñez, Parejo, Feu & Cañadas, 2011). It is therefore important to bear in mind that the risk of injury is greater in lower categories than at the elite level due to the game dynamic of shorter attacks and more transitions and game actions. Batteries of specific tests that can be used as training tasks and assessment tests including intervallic changes of speed simulating competitive demands for aerobic and anaerobic exercise (Ibáñez, Sáenz-López, & Gutiérrez, 1995a, 1995b), should be used to physically prepare and assess referees during their training (Mancha-Triguero, García-Rubio & Ibáñez, 2019). Another fundamental indicator in the analysis of the performance profile of the basketball referee is the accumulated accelerometer load (Player Load) which makes it possible to discover the physical demands that may cause a risk of injury because of the type of locomotion and specific movements of the sports discipline (García-Santos, Pino-Ortega et al., 2019a; Gómez-Carmona et al., 2020). This variable, together with the number of impacts will be one of the most predictive indicators of referees' performance in competition, as it explains most of the variables of external and internal load analysed (García-Santos et al., 2020b). In basketball, several studies have concluded that the referees presented lower levels of these variables of neuromuscular external load than players (Leicht et al., 2019; Leicht et al., 2020), due to the fact that the movements of the former are limited by the zones of action and responsibility during the game. With regard to the load dynamic during the match, previous studies have shown a decrease throughout the match (Leicht et al., 2020; García Santos et al., 2019b; Vaquera et al., 2017; Rojas-Valverde et al., 2020). In contrast, the present study found higher values in the last two periods. This may be related with the game dynamic, bearing in mind that the last two periods were where there was a greater difference in the score, and a previous investigation indicated that basketball referees face higher demands in external load in unbalanced matches (Rojas-Valverde et al., 2020). Thus, an unbalanced match in which there are fewer interruptions in the game will directly affect the external load supported by the basketball referee, increasing the demands due to the greater number of transitions and attacks. This is of vital importance for training, so the referees should be prepared both in close and balanced matches with longer attacks and more interruptions and in unbalanced matches with more transitions.

Finally, it is worth mentioning that this study is the first to analyse the demands faced by basketball referees according to the game action. It is therefore a pioneering study which follows the line of others that have used the game period or differences in the score as a factor of analysis (Rojas-Valverde et al., 2020). It has been shown that referees experience higher levels of internal load in situations of positional attack and transition, that is, those in which the game necessarily involves activity on the part of the referee. It should also be highlighted that more than 75% of the distance covered by the referees during the match corresponds to these two actions, which is equivalent to more than 3000 metres in specific situations that make it possible to make progress in the characterisation of the profile of refereeing performance. Therefore, the specific training of basketball referees should involve the execution of intermittent actions, with phases of high intensity (P and T) and periods of low intensity (DBC, DBW, DBFT). The intervallic character of the referee's intervention, with differentiated demands according to the specific game actions, has thus been demonstrated, and should be taken into account in their training. In the same line of thought, it is in the actions of transition when the highest levels of S_{MEAN} and S_{MAX} are reached. Specifically, referees cover a distance in transitions of approximately 900 metres at a speed greater than 12 km/h, almost 90% of the total distance covered in a match at this speed. Lastly, only 700 impacts of the almost 5400 in total were produced in actions that did not represent transition or positional attack. It is also noteworthy that 65% of the total player load is included in transition actions. These are the actions which represent the highest degree of physical demand for the referee, as they are situations in which the team that is attacking tries to advance to the opponent's basket without the opponents managing to establish a clear defensive system. Thus, the body of referees should focus their efforts in physical preparation on those scenarios that most imitate the real dynamic of the game.

5. CONCLUSIONS

The basketball referee's profile in official competition shows a total distance covered of 4 km, with approximately 75% walking or jogging, at an average speed greater than 5 km/h and reaching maximum speeds of over 25 km/h. The demands for intermittent locomotion during the game produced a total of 2300 accelerations and decelerations, which implied more than 5300 impacts and a player load of more than 36 a.u. These demands of external load affect the demands of internal load where the referees worked at around 82% of their maximum heart rate, reaching periods with demands higher than 160 bpm. The indicators of internal load *(*HR_{MAX}, %HR_{MAX}, HR_{MEAN} and Zones of % HR_{MAX}) were influenced by the *Game period* recording greater demands in the first quarter with respect to the last quarter of the match. In contrast, the *Game action* had a determinant effect in the demands of external load (Distance, Accelerations, Decelerations*,* S_{MAX}, S_{MEAN}, V1, V2, V3, V4, Impacts and player load), with higher demands in transition actions, where referees need to rapidly move towards the opponent's court to be in the best situation for making decisions on the game.

6. PRACTICAL APPLICATIONS

Monitoring internal and external load in official competitions or during training makes it possible to have an objective assessment of physical performance, which is useful information for establishing individual performance profiles and being able to plan competition and training more efficiently. This knowledge of the demands will also be of vital importance for designing assessment tests of the referees' physical fitness that are suitable for the intermittent demands prevalent in the real context. This is because the demands on the referees are very high in their movement in transition actions. In this respect, it is also proposed to modify the structure of training in which they do not only use continuous running in a straight line for aerobic and anaerobic work, but also incorporate high intensity interval training with changes of pace, changes of direction and actions at maximum speed in which they have to make decisions with a high physical demand, which will lead to having more specific preparation and obtaining maximum performance in decision making in competition. Bearing in mind the structure of the work identified in top competition referees, it would be advisable to design an interval training circuit in which sequences are included that are similar to those that the referees face in competition.

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