García-Santos, D.; Pino-Ortega, J.; García-Rubio, J.; Vaquera, A.; Ibáñez, S.J. (2022) Relationship between External and Internal Load in Basketball Referees. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 22 (87) pp. 615-633 Http://cdeporte.rediris.es/revista/revista87/artrelacion1349.htm
DOI: https://doi.org/10.15366/rimcafd2022.87.012

ORIGINAL

RELATIONSHIP BETWEEN EXTERNAL AND INTERNAL LOAD IN BASKETBALL REFEREES

RELACIÓN ENTRE LA CARGA INTERNA Y EXTERNA EN ÁRBITROS DE BALONCESTO

García-Santos, D.[1], Pino-Ortega, J.[2], García-Rubio, J.[3], Vaquera, A.[4] & Ibáñez, S.J.[5]

[1] PhD Student in Sport Science. Faculty of Sports Sciences and Physical Activity, University of Extremadura. Member of Research Group to Optimization of Training and Performance Sports (Spain) dgarcianu@alumnos.unex.es
[2] Doctor and Professor in the Faculty of Sports Science and Physical Activity, University of Murcia (Spain) josepinoortega@um.es
[3] Doctor and Professor in the Faculty of Sport Sciences and Physical Activity, University of Extremadura. Member of Research Group to Optimization of Training and Performance Sports (Spain) jagaru@unex.es
[4] Doctor and Professor in the Faculty of Sport Science and Physical Activity, University of Leon (Spain) avaqj@unileon.es
[5] Doctor and Professor in the Faculty of Sports Sciences and Physical Activity, University of Extremadura. Member of Research Group to Optimization of Training and Performance Sports (Spain) sibanez@unex.es

Spanish-English translators: Diana Schofield Smith, schofielddiane@gmail.com

ACKNOWLEDGMENT

This work has been partially subsidized by the Aid to Research Groups (GR21149) from the Government of Extremadura (Department of Economy and Infrastructure); with the contribution of the European Union throught the FEDER. To thanks the collaboration from Referees Area of International Basketball Federation.

Código UNESCO / UNESCO Code: 5899 Otras Especialidades Pedagógicas (Educación Física y Deporte) / Other Pedagogical Specialties (Physical Education and Sport)
Clasificación Consejo de Europa / Council of Europe Classification: 17. Otras (Rendimiento Deportivo) / Other (Sport Performance)

Recibido 15 de marzo de 2020 **Received** March 15, 2020
Aceptado 21 de abril de 2020 **Accepted** April 21, 2020

ABSTRACT

The quantification of referees' loads is playing an increasingly important role in the scientific field thanks to the professionalisation and advances achieved by referees. The aim of the present paper consists in analysing the relations between their internal (objective and subjective) and external load parameters. The sample was composed of a total of 15 matches played in the women's U16 Eurobasket championship, in which a total of nine referees (6 men and 3 women) participated. The internal load variables analysed were heart rate (%HRmax) and the subjective rating of perceived exertion (RPE). The external load variables were divided into kinematic (accelerations, speed and distance) and neuromuscular (Player Load, Metabolic Power and Impacts) variables, measured using inertial devices. The results show that there are associations between the values of objective internal load and external load, as well as between the variables of external load. In contrast, there is no relation between internal subjective load (RPE) and the variables of objective internal and external load, except regarding Metabolic Power. These results indicate that the competition and the level of the referees greatly influence the subjective variables. Moreover, it is necessary to be familiar with different methods for measuring referees' performance indicators for them to be able to adapt to the needs and possibilities offered by the competitive context.

KEYWORDS: Basketball Referee, Objective Internal Load, Subjective Internal Load, Objective External Load.

RESUMEN

La cuantificación de la carga del árbitro está adquiriendo un papel cada vez más importante dentro del ámbito científico debido a la profesionalización y avance del colectivo arbitral. El objetivo del presente trabajo consistió en analizar las relaciones existentes entre los parámetros de carga interna (objetiva y subjetiva) y externa. La muestra estuvo compuesta por un total de 15 partidos disputados en el Eurobasket femenino U-16, donde participaron un total de nueve árbitros (6 masculinos y 3 femeninos). Las variables analizadas de carga interna fueron la frecuencia cardiaca (%HRmax) y la percepción subjetiva de esfuerzo (RPE). Las variables de carga externa se dividieron en cinemáticas (aceleraciones, velocidades y distancias) y neuromusculares (PlayerLoad, PowerMetabolic e Impactos), medidas a través de dispositivos inerciales. Los resultados explican que existen relaciones entre los valores de carga interna objetiva y carga externa, así como entre las variables de carga externa. En cambio, no existen relaciones entre la carga interna subjetiva (RPE) y las variables de carga interna y externa objetiva, exceptuando el PowerMetabolic. Estos resultados demuestran que la competición y el nivel de los árbitros influyen en gran medida en las variables subjetivas. Además, es necesario conocer diferentes métodos para la medición de indicadores de rendimiento del árbitro, para poder adaptarse a las necesidades y posibilidades del contexto de juego.

PALABRAS CLAVE: Árbitros de Baloncesto, Carga Interna Objetiva, Carga Interna Subjetiva, Carga Externa Objetiva.

1. INTRODUCTION

The monitoring and quantification of the physical demands experienced by athletes are essential for optimising their performance (Weston et al., 2012), establishing training programmes adapted to the needs of each sport (Castillo, Weston, McLaren & Yanci, 2016) and reducing the risk of injury (Bartlett, O'Connor, Pitchford, Torres-Ronda & Robertson, 2017). It is therefore necessary to analyse the context in which the competition is held (Vaquera, Mielgo-Ayuso, Calleja-González & Leicht, 2016), and to know the particular characteristics of the sport.

Basketball is a sport that has undergone immense changes in its rules over time (Cormery, Marcil & Bouvard, 2008), which has meant that it has become a faster and more attractive game for spectators (Allegretti et al, 2015). The development of the sport has led to the improvement and professionalisation of the referees, providing them with a more important role in the competition where they are considered as another athlete in the game. From this viewpoint, the analysis of the referee's load is essential to be able to accurately establish his or her performance profile (García-Santos, Gamonales, León, Mancha & Muñoz, 2017), and thus achieve better refereeing practice (Myers, Feltz, Guillén & Dithurbide, 2012).

Referees' performance can be analysed from several points of view, making it possible to acquire a more complete understanding of their performance profiles. In the present study, it is possible to analyse the anthropometric profile (Castillo, Cámara & Yanci, 2019) and the demands of the internal (physiological) and external (kinematic and neuromuscular) loads (Bartlett et al, 2017). There are several tools that make it possible to record these internal and external demands in athletes. Some of them permit subjective quantification of the load, the most common of which for sports performance is the rating of perceived exertion (RPE) (Borg, 1982), which uses a Likert type scale from 0 to 10 according to the perceived effort made by the athlete. These tools of subjective perception of effort require prior training to be able to use them, the part of the players or referees, in order for the data to be valid and reliable (Castagna, Bizzini, Póvoas & D´Ottavio, 2017; McLaren, Graham, Spears & Weston, 2016).

From the objective point of view, the most commonly used method to analyse internal load is by recording heart rate (HR) (Matković, Rupčić & Knjaz, 2014; Vaquera, Mielgo-Ayuso, Calleja-González & Leicht, 2017). It is a measure which denotes the intensity of the exercise due to its close relationship with the stimulation of the organism (Karvonen, Kentala & Mustala, 1957). In sports refereeing, HR together with RPE have been the load indicators most commonly used to analyse referees' internal loads (Vaquera et al., 2017), as they are easy and low-cost methods. In fact, there is a strong correlation between these methods for assessing objective and subjective internal load, especially in contexts of high intensity (Costa et al., 2013; Weston, Bird, Helsen, Nevill &Castagna, 2006). On the other hand, there are another methods for analysing internal and external load in players and referees, like measuring lactate (Tessitore, Cortis, Meeusen & Capranica, 2007), maximum oxygen consumption (VO_2máx) (McLaren et al, 2016), cortisol (Moreira, McGuigan, Arruda, Freitas & Aoki, 2012) or testosterone (Schelling, Calleja-González, Torres-Ronda & Terrados, 2015). Specific equipment and expertise are necessary for these analyses, as they can alter the athletes' routines during the competition.

External load is defined as the mechanical and locomotor stress caused by the sports activity (Bucheit, Lacome, Cholley & Simpson, 2018), with kinematic and neuromuscular variables that analyse respectively the locomotion and its intensity and the force exerted between the interaction of gravity and the agents of the game (García-Ceberino, Antúnez, Feu & Ibáñez, 2020). In this sense, there are different electronic performance tracking systems (EPTS), like video-based tracking (Allegretti et al., 2015; Nabli et al., 2017), the Global Navigation Satellite System (GNSS) (Malone, Lovell, Varley & Coutts, 2017; Gómez-Carmona & Pino-Ortega, 2016) or the Local Position System (LPS) with ultra-wideband (UWB) technology (Alarifi et al., 2016; García-Santos, Pino-Ortega, García-Rubio, Vaquera & Ibáñez, 2019b). In the first case, the kinematic analysis is carried out using mathematical algorithms and a series of cameras that make it possible to follow the game and participants. With the GNSS and LPS systems, the athletes have to wear the device on their backs in an anatomically designed harness to be able to record the data. Furthermore, the LPS with UWB technology, make it possible to analyse load variables in indoor sports thanks to a system of antennae using radiofrequency (Bastida-Castillo et al., 2019). Some of these systems provide information in real time thanks to ANT^+ technology, which means more accurate monitoring of the referee, as they determine kinematic (distance covered, accelerations, speeds, etc.) and neuromuscular (Player Load, Metabolic Power and Impacts) variables that make it possible to exactly ascertain the load involved in a match in real time (Reina, García-Rubio, Antúnez & Ibáñez, 2020), as well as the fatigue index produced (Barrett, 2016). All of which will make it possible to better adapt to the characteristics of play (Matković et al., 2014) and work on the aspects that the referees need to improve in relation to internal and external load.

After reviewing the existing literature, no investigations were found that triangulated and related the information coming from different assessment systems on the load experienced by basketball referees during competition. Thus, the present study is focused on characterising the objective and subjective internal and objective external loads in basketball referees during competition and identifying the relations among these performance indicators, to be able to determine which tools to use according to resources and possibilities.

2. MATERIALS AND METHODS

2.1 DESIGN

The present investigation used a transversal design with natural groups (Ato, López & Benavente, 2013), to evaluate the correlations between the external and internal loads of basketball referees.

2.2 PARTICIPANTS

The population that participated in the present study was composed of nine international referees, six men (M) and three women (W), who participated in the women's U16 Eurobasket championship in Gibraltar 2017. The anthropometric characteristics of the participants are presented in *figure 2*. The referees were informed at the beginning of the investigation of the experimental protocol and the possible benefits and signed their informed consent. The procedures followed in the present study were approved by the Ethics Committee of the University of Extremadura (Ref. 67/2017), according to the Declaration of Helsinki (2013). The International Basketball Federation (FIBA) authorised the participation and monitoring of all the referees during the championship.

2.3 SAMPLE

The sample was made up of the data obtained from the fifteen matches played as a tournament during the Women's U16 Eurobasket championship. Three referees participated in each match, appointed by the FIBA Referee Technical Committee. All the referees participated the same number of times. The matches were divided into four periods of ten minutes. There was a break of two minutes between the first and second and third and fourth quarters, and of ten minutes between the second and third quarter.

2.4 VARIABLES

The following variables were used in this study to ascertain the internal and external loads of the basketball referees during the competition and quantify their performance:

Objective Internal Load (iTL)

The iTL is determined by the percentage of the maximum heart rate *(%HRmax)*, making it possible to determine the intensity of the effort. The levels of effort were established by dividing the maximum into five different zones according to Vaquera et al., (2017) *(Z1: 50-60%, Z2: 60-70%, Z3: 70-80%, Z4: 80-90%, Z5: 90-95%, Z6: >95%).* HRmax was calculated using an adaptation of the formula proposed by Whaley, Kaminsky, Dwyer, Getchell & Norton, (1992), both for men and women:

Men

$$HRmax\ (bpm) = 203.9 - [0.812 * Age] + [0.276 * HRbasal] - [0.084 * Body\ Mass]$$

Women

$$HRmax\ (bpm) = 204.8 - [0.718 * Age] + [0.162 * HRbasal] - [0.105 * Body\ Mass]$$

Objective Kinematic External Load (eTL_k*)*

Several variables were recorded to assess the eTL_k, like maximum velocity (Vmax), mean velocity (Vmean), number of accelerations (Acc) and decelerations (Dec), accelerations (Acc/m) and decelerations per minute (Dec/m), total distance covered (Dis) and per minute (Dis/m), and total number of steps (St) and steps per minute (Dis/m). Maximum and mean velocity of the referees were both expressed in metres per second (m/s), and the number of accelerations and decelerations performed during the match were also calculated, and accelerations and decelerations per minute were expressed in (m/s^2). The total distance covered and distance per minute were recorded in metres. The total number of steps and steps per minute were also recorded.

Objective Neuromuscular External Load (eTL_N*)*

The eTLn was expressed using Impacts (Imp), Metabolic Power (PMet) and Player Load (PL). Both PL and PMet were calculated per minute as well as in the total match. While the Imp were calculated only the total of the game. The Imp make it possible to calculate the G force acting on the referee during the different game actions (Puente, Abián-Vicén, Areces, López & Del Coso, 2017). The vector sum is calculated of the G forces in the three planes (x, y and z). In the present investigation, they were determined when their value was greater than 5Gs.

PMet was determined by multiplying the velocity (V) by the energy cost of the activity (EC) derived from the inclination and acceleration (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010) according to the following formula:

$$PMet = EC \cdot V$$

The PL variable was used to evaluate the neuromuscular external load of the referees (Cormack, Mooney, Morgan & McGuigan, 2013), having previously shown its reliability and validity (Barrett, 2016; Barreira et al., 2017). It was calculated using the vector sum of the four points of accelerations in the three axes (vertical, middle-lateral and antero-posterior). Its unit of measure is represented by arbitrary measures (a.u.). The equation used for its calculation was:

$$PlayerLoad_{t=n} \sum_{t=0}^{t=n} \sqrt{\frac{(Z_{t=i+1} - Z_{t=i})^2 + (X_{t=i+1} - X_{t=i})^2 + (Y_{t=i+1} - Y_{t=i})^2}{100}}$$

Where (*Z*) is acceleration in the antero-posterior axis, (X) acceleration in the medial lateral axis (*X*), and (*Y*) in the vertical axis, and (*t*) is time and (*n*) is number.

Subjective Internal Load (iTL_S)

The iTL_S was measured by the subjective rating of perceived exertion (RPE) using Borg's CR10 scale (Borg, 1982). It is a scale that establishes numerical values of 0-10 with zero representing the minimum value and 10 the maximum. This scale represents the subjective load experienced by a referee during the game and was recorded by each referee at the end of the match.

2.5 MATERIALS

Perceived exertion was rated using the Borg CR-10 scale (1982). Objective internal and external loads were measured with GARMIN® heart rate monitors and WIMU-PRO^{TM} (Realtrack System, Almería, Spain) inertial devices, respectively. The device possesses several positioning sensors using ultra-wideband (UWB) technology. These devices make it possible to objectively monitor the athlete. S-PRO^{TM} (RealTrack Systems, Almería, Spain) software was used to analyse the recorded data. A system of six interconnected radiofrequency antennae with a sampling frequency of 18Hz permitted recording data from these devices in indoor conditions. The protocol for fixing the device to the subject and setting up the antenna system are shown in *figure 1*, representing on the left the place where the WIMU-PRO^{TM} device is located and on the right the positioning of the six antennae on the court.

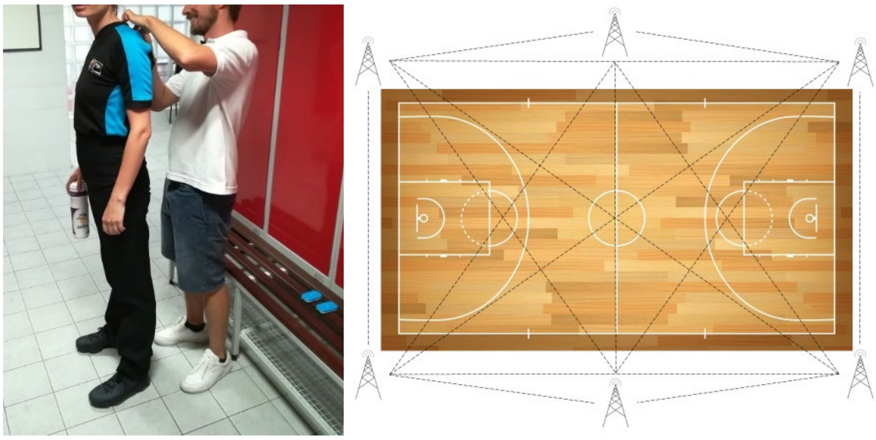

Figure 1. *Introduction of the WIMU PRO device on specific harness and placing it in one of the participating subjects in this research and Antennas Systems placement.*

2.6 STATISTICAL ANALYSIS

First an exploratory analysis was performed to decide on the model with which to confirm the hypothesis (Field, 2013), with the Shapiro-Wilk normality test, the Rachas randomness test and the Levene test for homocedacity. The assumption of criteria analysis determined that the variables fulfilled the criteria for a parametric test of the hypothesis.

The descriptive statistics (mean, standard deviation) were then calculated for each variable. The relation between variables was then analysed using Pearson's correlation (*r*), to ascertain the strength of the relation. The ranges established for the correlations were *weak (0.1-0.3), moderate (0.3-0.5), strong (0.5-0.7), very strong (0.7-0.9), almost perfect (>0.9) and perfect (1)* (Field, 2013). Finally, a lineal regression (r^2) was performed to ascertain where these correlations occurred and check in what percentage the independent variables (objective and subjective internal load variables) explain the changes produced in the dependent variables (external load). The significance level used in the different analyses was $p<0.05$, and the software package used was IBM SPSS Statistics for Windows, Versión 21.0. Armonk, NY: IBM Corp.

3. RESULTS

The results of the different analyses are presented below. First, *figure 2* shows the average of the anthropometric values of referees, both male and female.

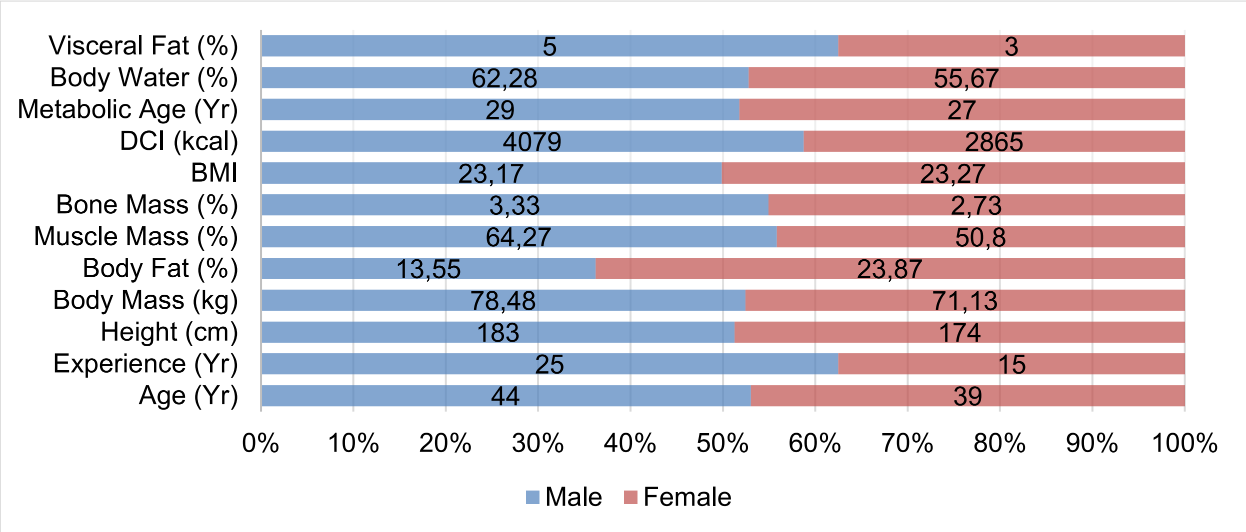

Figure 2. *Anthropometric Data.*

Table 1 presents the descriptive data (mean and standard deviation) of each of the studied variables.

Table 1. *Descriptive results of the variables of internal and external load.*

Variables		*n*	*Mean*	*SD*
iTL	%HRmax	45	61,84	7,18
eTLk	Accelerations (m/s^2)	45	1079	192
	Decelerations (m/s^2)	45	505	138
	Acc/min (m/s^2)	45	13,65	1,92
	Dec/min (m/s^2)	45	6,40	1,68
	VMax (km/h)	45	18,91	1,17
	VMed (km/h)	45	4,87	0,21
	Steps	45	2616	543
	Steps/min	45	33	6
	Distance (m/s)	45	4330	603
	Distance/min (m/s)	45	55	5
eTL_N	PlayerLoad^{TM}	45	44,13	7,92
	PlayerLoad^{TM}/min	45	0,56	0,08
	Metabolic Power	45	15,60	2,57
	Metabolic Power/min	45	0,20	0,03
	Impacts	45	1024	372
iTL_S	RPE	45	2,02	1,01

Note: *iTL= Objective internal load; eTLk= Kinematic external load; eTL_N= Neuromuscular external load; iTL_S= Subjective internal load; n=Nº of total periods; SD=Standard deviation; %HRmax=Percentage of maximum heart rate; RPE=Rated perceived exertion; Acc/min=Accelerations per minute; Dec/min=Decelerations per minute; VMax=Maximum velocity; VMed: Mean velocity.*

Table 2 presents the relations between the objective and subjective internal load and the variables of kinematic and neuromuscular external load. The results show significant relations between different groups of variables, such as %HR and Vmed ($p\leq0.01$), St/m ($p\leq0.05$), Dis/min ($p\leq0.01$) and PL/min ($p\leq0.05$); accelerations and Vmax ($p\leq0.05$), Dis ($p\leq0.01$), PL ($p\leq0.01$) and PMet ($p\leq0.01$); Vmax and Dis/min ($p\leq0.01$), and PMet ($p\leq0.01$). The RPE had no relation with any of the variables of internal or external load, except PMet ($p\leq0.05$).

Table 2. *Result of the correlations.*

Variables			eTL_C										eTL_N					iTL_S
			Acc	Dec	Acc/m	Dec/m	Vmax	Vmed	St	St/m	Dis	Dis/m	PL	PL/m	PMet	PMet/m	Imp	RPE
iTL	%HRmax	r	0.10	0.15	0.23	0.21	0.25	0.50	0.25	0.34	0.27	0.51	0.10	0.20	0.24	0.32	-0.11	-0.12
		Sig.	0.50	0.33	0.14	0.16	0.10	0.00**	0.10	0.02**	0.07	0.00**	0.52	0.18	0.11	0.03**	0.46	0.41
eTL_c	Acc	r	1.00	0.91	0.62	0.62	0.34	-0.17	0.41	-0.02	0.80	0.17	0.46	-0.06	0.78	0.26	0.08	0.06
		Sig.		0.00**	0.00**	0.00**	0.02*	0.26	0.01**	0.88	0.00**	0.26	0.00**	0.67	0.00**	0.09	0.60	0.67
	Dec	r		1.00	0.80	0.87	0.48	0.03	0.27	0.07	0.67	0.43	0.26	-0.00	0.71	0.48	-0.09	-0.06
		Sig.			0.00**	0.00**	0.00**	0.83	0.07	0.64	0.00**	0.00**	0.09	0.98	0.00**	0.00**	0.55	0.66
	Acc/m	r			1.00	0.96	0.51	0.18	0.04	0.22	0.26	0.64	-0.03	0.16	0.38	0.64	-0.22	-0.17
		Sig.				0.00**	0.00**	0.24	0.77	0.14	0.08	0.00**	0.84	0.30	0.01*	0.00**	0.14	0.27
	Dec/m	r				1.00	0.56	0.24	0.07	0.22	0.33	0.67	-0.02	0.14	0.44	0.68	-0.25	-0.21
		Sig.					0.00**	0.11	0.66	0.14	0.03*	0.00**	0.87	0.37	0.00**	0.00**	0.10	0.15
	Vmax	r					1.00	0.30	0.16	0.20	0.32	0.47	0.03	0.07	0.37	0.49	-0.15	-0.11
		Sig.						0.04*	0.28	0.17	0.03*	0.00**	0.84	0.65	0.02*	0.00**	0.31	0.47
	Vmed	r						1.00	0.12	0.44	0.14	0.80	0.18	0.63	0.10	0.49	0.12	-0.24
		Sig.							0.44	0.00**	0.34	0.00**	0.23	0.00**	0.51	0.00**	0.45	0.11
	St	r							1.00	0.73	0.62	0.19	0.74	0.41	0.42	-0.00	0.36	-0.07
		Sig.								0.00**	0.00**	0.28	0.00**	0.01**	0.00**	0.98	0.01*	0.65
	St/m	r								1.00	0.12	0.53	0.34	0.65	-0.00	0.22	0.15	-0.25
		Sig.									0.43	0.00**	0.02*	0.00**	0.99	0.15	0.32	0.10
	Dis	r									1.00	0.28	0.72	0.14	0.85	0.23	0.25	0.02
		Sig.										0.06	0.00**	0.37	0.00**	0.12	0.10	0.91
	Dis/m	r										1.00	0.10	0.54	0.29	0.73	-0.13	-0.27
		Sig.											0.51	0.00**	0.05	0.00**	0.40	0.07
eTL_n	PL	r											1.00	0.61	0.55	0.00	0.74	-0.05
		Sig.												0.00**	0.00**	0.99	0.00**	0.75
	PL/m	r												1.00	0.06	0.28	0.58	-0.26
		Sig.													0.67	0.06	0.00**	0.08
	PMet	r													1.00	0.57	0.13	-0.11
		Sig.														0.00**	0.39	0.49
	PMet/m	r														1.00	-0.18	-0.38
		Sig.															0.24	0.01**
	Imp	r															1.00	0.13
		Sig.																0.39

Note: *iTL=Objective internal load; eTLk= Kinematic external load; eTLN= Neuromuscular external load; iTLS= Subjective internal load; %HRmax=Percentage of maximum heart rate; Acc=Accelerations; Dec=Decelerations Acc/min=Accelerations per minute; Dec/min=Decelerations per minute; VMax=Maximum velocity; VMed:Mean velocity; St=Steps; St/m=Steps per minute; Dis=Distance covered; Dis/m=Distance covered per minute; PL= Player load; PL/m= Player load per minute; PMet= Metabolic power; PMet/m= Metabolic power per minute; Imp=Impacts; RPE=Rated perceived exertion; r=Pearson's r; *=p≤0.05; **=p≤0.01.*

Table 3. *Results of the lineal regression.*

		eTLk	eTL_N	eTLk + eTL_N	iTL
iTL	R^2	0.357	0.206	0.599	
	D-W	2.221	2.188	2.164	
	Sig.	0.081	0.096	0.007**	
iTL_S	R^2	0.215	0.299	0.454	0.016
	D-W	1.439	1.586	1.695	1.150
	Sig.	0.308	0.013**	0.188	0.414

Note: *iTL= Objective internal load; eTLk= Kinematic external load; eTL_N= Neuromuscular external load; iTL_S= Subjective internal load; D-W=Durbin-Watson; **=p≤0.01.*

The results of the lineal regression (Table 3) show that 60% of the variance of the kinematic and neuromuscular external load variables are explained by the objective internal load variable (%HRmax) with a D-W value near to 2 which determine the reliability and collinearity of the data (Field, 2009). Similarly, 30% of the variance of the neuromuscular external load variables, that is P/Met is explained by the subjective internal load variable (RPE). The rest of the variables do not present any type of significance.

4. DISCUSSION

The objective of the present study was to establish the relations between the different variables of internal and external load in an objective and reliable way using inertial devices and comparing them with a subjective method like RPE. The results explain that there are significant relations between the objective variables studied, so the use of these devices is beneficial for the objective quantification of a referee's performance (García-Santos et al., 2017), as well as for reducing the risk of injury in the athlete (Colby, Dawson, Heasman, Rogalski & Gabbett, 2014). Furthermore, it can be seen that with the exception of PMet, none of the objective variables analysed show a relation with the subjective variable of RPE. To further understanding of the data obtained, the relations between the different groups of variables, are shown below, following the order established in the tables of results.

Regarding the relation between objective variables of iTL and eTL_K, it can be seen that %HR has a moderate positive relation with Vmed and Dis/min, and a weak relation with St/min. It is therefore important to know Vmed, Dis/min and St/min to determine the referee's cardiovascular stress during the game., as the duration, type and velocity of movement, as well as the load imposed on the referee are associated in a basketball match with a concrete cardiovascular response (McLaren et al., 2017). Thus, a match that shows high indices of cardiovascular stress can be characterised by a fast game pace, based on rapid transitions and terminations of the different play actions. This type of matches is common at the training stage (García-Santos et al., 2019a), as shown in the present study.

Regarding the relation between iTL and eTL_N, there was only a positive relation between %HR and PMet/min in the present investigation. This single correlation is because the energy cost represented by the PMet is intimately related to the aerobic capacity and oxygen consumption of the referee during his intervention (Hoppe, Baumgart, Slamka, Polglaze & Freiwald, 2017), influential factors in the cardiovascular profile of an athlete. With respect to the Player Load variables, it is possible that there is no relation because the referees always record lower values in this variable than the players (Leicht et al., 2019), but depending on the intensity of the competition it can affect to HR or not. Lastly, regarding the possible relation between HR and the impacts, it can be observed that the impacts influentially influence to referee's cardiovascular stress, since the only contact made by the referee above 5G is during high intensity running, as they usually do not jump or contact with players.

The data obtained on the relation between the variables that explain the referee's iTL and eTL show that there is no significant correlation between %HRmax and RPE. This may be due to the fact that the referees were accustomed to refereeing top-level matches with higher physical loads, as they were international referees for adult competitions refereeing matches in the U16 category. However, there are studies that report a high correlation between %HRmax and RPE, but in situations of high intensity (Costa et al., 2013; Vaquera et al., 2017; Weston et al., 2006), because, as explained by Marcora, Staiano & Manning (2009), the perception of fatigue is associated with high values in the cardiovascular and bioenergy systems, especially in situations at the end of a match when mental fatigue is greater than physical fatigue. Thus, some studies affirm that both the heart rate (Matkovic et al., 2014; Vaquera et al., 2016), and RPE (Castagna, et al., 2017) can be used as reliable indicators of a referee's performance, the RPE being a standard tool for indicating iTLs (McLaren et al., 2016), due to its low cost. Suitable prior training is necessary when using this tool (Gallo et al., 2015), as it is simpler to predict performance in more experienced referees who are more familiar with it (Bartlett et al., 2016). The analysed data show that the iTL was higher than the referees' own recorded perceptions.

Similarly, there are correlations between eTL_K and eTL_N load variables. It is possible to specify that the kinematic variables (acceleration, velocity and distance) have a strong relation with the neuromuscular variables (PL and PMet). A stable relation also exists between steps and impacts. These results show the importance of knowing the speed reached by a referee to cover a determined distance during a match, as well as the number of accelerations and decelerations performed (Gómez-Carmona & Pino-Ortega, 2016), in order to establish the load in each match, as every match is different and the referee must adapt his or her movements to the needs of the game. In this respect, recent studies determine that the neuromuscular variables (PL™, PMet and Impacts) are the most predictive for ascertaining athletes' performance (Schelling & Torres, 2016; Aoki et al., 2017), as they are indicators which are closely related to velocity, distance and acceleration (Hoppe et al., 2017). There are also other types of movements associated with referees such as running sideways and backwards that involve a high physical demand and can be quantified thanks to the PL™. The sum of these movements establishes the value of the load experienced by the referee during the competition, information which is necessary as it may point to the existence of injury risk (Barreira et al., 2017); even more so when the competitive period is limited and referees have to referee in more than one match or on consecutive days. In this respect, the PMet makes it possible to establish the load profiles (Oxendale, Highton, & Twist, 2017) and the fatigue index (Barret, 2016), through data on the energy cost of a referee during the match, so it is normal for it to be associated with the kinematic variables as they are the most predictive of fatigue. The inertial devices with UWB technology (Bastida-Castillo et al., 2019; García-Santos et al., 2019;) have been very useful for quantifying this type of variables in indoor competition, as they accurately establish the data on each one (Serpiello et al, 2017).

In contrast, the present study found no relations between iTLs and eTL_K. However, according to Bartlett et al. (2016), the distance covered at high intensity, mean velocity and accelerations have a close relation with the rated perceived exertion of players in training situations. It is not known how they may influence competitive situations, or referees using Borg's CR-10 scale (1982).

Nevertheless, if attention is paid to the possible relations between load variables iTLs and eTL_N, the present study only shows a negative correlation between PMet/min and RPE. This is due to the strong association between aerobic capacity and oxygen consumption and the subjective perception of the referees themselves (Osgnach et al., 2010; Hoppe et al., 2017). Other studies affirm that there is a close relation between PL^{TM} and RPE values, but these have been established during training sessions in football (Gaudino et al., 2015), rugby (Lovell, Sirotic, Impellizzeri & Coutts, 2013) or Australian football (Gallo et al., 2015) players. To date no studies have been found that analyse these relations in referees from different sports, nor in specific competitive situations, as in the present investigation, where furthermore the lack of training in the use of the RPE instrument may have had some influence. It would also be advisable to bear the competitive level in mind, as the participating referees were accustomed to a higher game pace and recorded low RPE values.

Thus, it can be specified that knowledge of the load variables of iTL and eTL using inertial devices makes it possible to establish reliable and objective data on the different physical parameters that influence a referee's performance during competition (Gómez-Carmona & Pino-Ortega, 2016), making it possible in this way to institute feedback and individualised training methods adapted to the characteristics of each referee (García-Santos & Ibáñez, 2016) and to the context of the respective competition (Castillo et al., 2016), with the aim of favouring decision-making and improving the referee's performance during the competition (Ahmed et al., 2017). It is also possible to conclude that an adequate use of the rated perceived exertion scale can determine the physiological performance of a referee, in the absence of more reliable and expensive tools, although the competitive level can also be of consequence.

6. CONCLUSIONS

These findings make it possible to establish that in the present study there were no relations between objective internal and external load and subjective internal load, with the exception of the relation between the subjective internal load and PMet, due to the differences between the level of the competition and that of the referees, accustomed to refereeing matches in higher categories. It would be convenient to carry out in future research to analyse these relationships in higher level competitions, to see if the level of competition affects the relationships between objective and subjective load variables.

Instead, similarities were found between the objective internal load variables and those of the external load, and those of the variables of external load among themselves. This means that all the variables that predict the physical performance of the referee are interrelated and vary according to the competitive conditions. Moreover, they make it possible to ascertain the work load of a referee during an official match, as well as his or her own needs.

It is necessary to state that there are different objective and reliable resources and methods for monitoring the referee in real time and in the competitive context. The use of these devices will make it possible to establish training programmes adapted to the real characteristics of a match and improve the referee’s performance during the competition.

7. REFERENCES

Ahmed, H., Davison, G., & Dixon, D. (2017). Analysis of activity patterns, physiological demands and decision-making performance of elite Futsal referees during matches. *International Journal of Performance Analysis in Sport*, *17*(5), 737-751. doi: 10.1080/24748668.2017.1399321

Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M. A., & Al-Khalifa, H. S. (2016). Ultra-wideband indoor positioning technologies: Analysis and recent advances. *Sensors*, *16*(5), 707. doi: 10.3390/s16050707

Allegretti, L. M., Misuta, M. S., Nicolletti, C., Monezi, I., Bonganha, V., Daniel, J. F., Cavaglieri, C. R., Borin, J. P., & Montagner, P. C. (2015). Distances covered per quarter by elite basketball referees in competition. *Gazzetta Medica Italiana*, *174*, 1-2.

Aoki, M. S., Ronda, L. T., Marcelino, P. R., Drago, G., Carling, C., Bradley, P. S., & Moreira, A. (2017). Monitoring Training Loads in Professional Basketball Players Engaged in a Periodized Training Program. *The Journal of Strength & Conditioning Research*, *31*(2), 348-358. doi: 10.1519/JSC.0000000000001507

Ato, M., López, J. J., & Benavente, A. (2013). A classification system for research designs in psychology. *Anales de Psicología*, *29*(3), 1038-1059. doi: 10.6018/analesps.29.3.178511

Barreira, P., Robinson, M. A., Drust, B., Nedergaard, N., Raja Azidin, R. M. F., & Vanrenterghem, J. (2017). Mechanical Player Load™ using trunk-mounted accelerometry in football: Is it a reliable, task-and player-specific observation? *Journal of Sports Sciences*, *35*(17), 1674-1681. doi:10.1080/02640414.2016.12290157

Barret, S. (2016). *The utility of PlayerLoadTM in Soccer: An examination of the reliability, validity, determinants and the within match patterns* (Thesis doctoral). University of Hull, United Kingdom.

Bartlett, J. D., O'Connor, F., Pitchford, N., Torres-Ronda, L., & Robertson, S. J. (2017). Relationships between internal and external training load in team-sport athletes: evidence for an individualized approach. *International Journal of Sports Physiology and Performance*, *12*(2), 230-234. doi:10.1123/ijspp.2015-0791.

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

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine Science Sports Exercise*, *14*(5), 377-381. https://doi.org/10.1249/00005768-198205000-00012

Buchheit, M., Lacome, M., Cholley, Y., & Simpson, B. M. (2018). Neuromuscular responses to conditioned soccer sessions assessed via GPS-embedded accelerometers: Insights into tactical periodization. *International Journal of Sports Physiology and Performance, 13*(5), 577-583. doi: 10.1123/ijspp.2017-0045.

Castagna, C., Bizzini, M., Póvoas, S. C. A., & D'Ottavio, S. (2017). Timing Effect on Training-Session Rating of Perceived Exertion in Top-Class Soccer Referees. *International Journal of Sports Physiology and Performance*, *12*(9), 1157-1162. doi:10.1123/ijspp.2016-0626.

Castillo, D.; Cámara, J. & Yanci J. (2019). Efecto de un periodo competitivo sobre el perfil antropométrico de árbitros de fútbol. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte,19*(73), 93-105. doi:10.15366/rimcafd2019.73.007

Castillo, D., Weston, M., McLaren, S. J., Cámara, J., & Yanci, J. (2016). Relationships Between Internal and External Match Load Indicators in Soccer Match Officials. *International Journal of Sports Physiology and Performance*, 1-21. doi:10.1123/ijspp.2016-0392

Colby, M. J., Dawson, B., Heasman, J., Rogalski, B., & Gabbett, T. J. (2014). Accelerometer and GPS-derived running loads and injury risk in elite Australian footballers. *The Journal of Strength & Conditioning Research*, *28*(8), 2244-2252. https://doi.org/10.1519/JSC.0000000000000362

Cormack, S. J., Mooney, M. G., Morgan, W., & McGuigan, M. R. (2013). Influence of neuromuscular fatigue on accelerometer load in elite Australian football players. *International Journal of Sports Physiology and Performance*, *8*(4), 373-378. doi:10.1123/ijspp.8.4.373

Cormery, B., Marcil, M., & Bouvard, M. (2008). Rule change incidence on physiological characteristics of elite basketball players: a 10-year-period investigation. *British Journal of Sports Medicine*, *42*(1), 25-30. doi:10.1136/bjsm.2006.033316

Costa, E. C., Vieira, C. M., Moreira, A., Ugrinowitsch, C., Castagna, C., & Aoki, M. S. (2013). Monitoring external and internal loads of Brazilian soccer referees during official matches. *Journal of Sports Science and Medicine*, *12*(3), 559–564.

Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics* (4th edition). London: SAGE.

Gallo, T., Cormack, S., Gabbett, T., Williams, M., & Lorenzen, C. (2015). Characteristics impacting on session rating of perceived exertion training load in Australian footballers. *Journal of Sports Sciences*, *33*(5), 467-475. doi: 10.1080/02640414.2014.947311

García-Ceberino, J. M., Antúnez, A., Feu, S., & J Ibáñez, S. (2020). Quantification of Internal and External Load in School Football According to Gender and Teaching Methodology. *International Journal of Environmental Research and Public Health, 17*(1), 344. doi: 10.3390/ijerph17010344

García-Santos, D., Gamonales, J. M., León, K., & Muñoz, J. (2017). A case study: characterization of physiological, cinematic and neuromuscular demands of handball referee during competition*. E-Balonmano: Revista de Ciencias del Deporte, 13*(3), 207-216. https://doi.org/10.6018/264601

García-Santos, D., García-Rubio, J.; Reina, M.; Pino-Ortega, J.; Vaquera, A. & Ibáñez, S. J. (2019a). Perfil de acelerometría de los árbitros de baloncesto durante el Eurobasket femenino U-16. *Journal of Sport Psychology, 28*(1), 55-64.

García-Santos, D., & Ibáñez, S. J. (2016). Diseño y validación de un instrumento de observación para la valoración de un árbitro de baloncesto *(IOVAB). SporTK-Revista EuroAmericana de Ciencias del Deporte, 5*(2), 15-26.

García-Santos, D., Pino-Ortega, J., García-Rubio, J., Vaquera, A., & Ibáñez, S. J. (2019b). Internal and External Demands in Basketball Referees during the U-16 European Women's Championship. *International Journal of Environmental Research and Public Health, 16*(18), 3421. https://doi.org/10.3390/ijerph16183421

Gaudino, P., Iaia, F. M., Strudwick, A. J., Hawkins, R. D., Alberti, G., Atkinson, G., & Gregson, W. (2015). Factors influencing perception of effort (session rating of perceived exertion) during elite soccer training. *International Journal of Sports Physiology and Performance, 10*(7), 860-864. doi:10.1123/ijspp.2014-0518

Gómez-Carmona, C., & Pino-Ortega, J. (2016). Kinematic and physiological analysis of the performance of the referee football and its relationship with decision making. *Journal of Human Sport and Exercise*, *11*(4), 397-414. doi:10.14198/jhse.2016.114.01

Hoppe, M. W., Baumgart, C., Slomka, M., Polglaze, T., & Freiwald, J. (2017). Variability of Metabolic Power Data in Elite Soccer Players During Pre-Season Matches. *Journal of Human Kinetics*, *58*(1), 233-245. doi:10.1515/hukin-2017-0083

Karvonen, M. J., Kentala, E. & Mustala, O. (1957). The effects of training on heart rate. *Annales Medicinae Experimentaliset Biologiae Fenniae, 35*(3), 307-315.

Leicht, A. S., Fox, J., Connor, J., Sargent, C., Sinclair, W., Stanton, R., & Scanlan, A. (2019). External Activity Demands Differ Between Referees and Players During a Sub-Elite, Men's Basketball Match. *Research Quarterly for Exercise and Sport,* 1-6. doi: 10.1080/02701367.2019.1645268

Lovell, T. W., Sirotic, A. C., Impellizzeri, F. M., & Coutts, A. J. (2013). Factors affecting perception of effort (session rating of perceived exertion) during rugby league training. *International Journal of Sports Physiology and Performance*, *8*(1), 62-69. https://doi.org/10.1123/ijspp.8.1.62

Malone, J. J., Lovell, R., Varley, M. C., & Coutts, A. J. (2017). Unpacking the black box: applications and considerations for using GPS devices in sport. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), S2-18. doi:10.1123/ijspp.2016-0236

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology*, *106*(3), 857-864. doi: 10.1152/japplphysiol.91324.2008

Matković, A., Rupčić, T., & Knjaz, D. (2014). Physiological load of referees during basketball games. *Kinesiology*, *46*(2), 258-265.

McLaren, S. J., Graham, M., Spears, I. R., & Weston, M. (2016). The sensitivity of differential ratings of perceived exertion as measures of internal load. *International Journal of Sports Physiology and Performance*, *11*(3), 404-406. doi: 10.1123/ijspp.2015-0223

McLaren, S. J., Macpherson, T. W., Coutts, A. J., Hurst, C., Spears, I. R., & Weston, M. (2017). The relationships between internal and external measures of training load and intensity in team sports: A meta-analysis. *Sports Medicine*, 1-18. doi: 10.1007/s40279-017-0830-z

Moreira, A., McGuigan, M. R., Arruda, A. F., Freitas, C. G., & Aoki, M. S. (2012). Monitoring internal load parameters during simulated and official basketball matches. *The Journal of Strength & Conditioning Research*, *26*(3), 861-866. https://doi.org/10.1519/JSC.0b013e31822645e9

Myers, N. D., Feltz, D. L., Guillén, F., & Dithurbide, L. (2012). Development of, and initial validity evidence for, the Referee Self-Efficacy Scale: A multistudy report. *Journal of Sport & Exercise Psychology, 34*(6), 737-765. doi: 10.1123/jsep.34.6.737

Nabli, M. A., Abdelkrim, N. B., Castagna, C., Jabri, I., Batikh, T., & Chamari, K. (2017). Energy Demands and Metabolic Equivalents (METS) in U-19 Basketball Refereeing During Official Games. *Journal Sports Medicine Doping Studies*, *7*(190), 2161-0673. doi: 10.4172/2161-0673.1000190

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: a new match analysis approach. *Medicine Science Sports Exercise*, *42*(1), 170-178. doi:10.1249/MSS.0b013e3181ae5cfd

Oxendale, C. L., Highton, J., & Twist, C. (2017). Energy expenditure, metabolic power and high speed activity during linear and multi-directional running. *Journal of Science and Medicine in Sport*, *20*(10), 957-961. doi: 10.1016/j.jsams.2017.03.013

Puente, C., Abián-Vicén J., Areces, F., López, R., & Del Coso, J. (2017). Physical and physiological demands of experienced male basketball players during a competitive game. *The Journal of Strength & Conditioning Research, 31*(4), 956-962. doi:10.1519/JSC.0000000000001577

Reina, M., Rubio, J. G., Antúnez, A., & Ibáñez, S. J. (2020). Comparación de la carga interna y externa en competición oficial de 3 vs. 3 y 5 vs. 5 en baloncesto femenino (Comparison of internal and external load in official 3 vs. 3 and 5 vs. 5 female basketball competitions). *Retos, 37*(37), 400-405. https://doi.org/10.47197/retos.v37i37.73720

Schelling, X., Calleja-González, J., Torres-Ronda, L., & Terrados, N. (2015). Using testosterone and cortisol as biomarker for training individualization in elite basketball: a 4-year follow-up study. *The Journal of Strength & Conditioning Research*, *29*(2), 368-378. doi: 10.1519/JSC.0000000000000642

Schelling, X., & Torres, L. (2016). Accelerometer Load Profiles for Basketball-Specific Drills in Elite Players. *Journal of Sports Science & Medicine*, *15*(4), 585.

Serpiello, F. R., Hopkins, W. G., Barnes, S., Tavrou, J., Duthie, G. M., Aughey, R. J., & Ball, K. (2017). Validity of an ultra-wideband local positioning system to measure locomotion in indoor sports. *Journal of Sports Sciences*, 1-7. Online. doi:10.1080/02640414.2017.1411867

Tessitore, A., Cortis, C., Meeusen, R., & Capranica, L. (2007). Power performance of soccer referees before, during, and after official matches. *Journal of Strength and Conditioning Research*, *21*(4), 1183. https://doi.org/10.1519/R-19905.1

Vaquera, A., Mielgo-Ayuso, J., Calleja-González, J., & Leicht, A. S. (2016). Sex differences in cardiovascular demands of refereeing during

international basketball competition. *The Physician and Sportsmedicine*, *44*(2), 164-169. doi:10.1080/00913847.2016.1158622
Vaquera, A., Mielgo-Ayuso, J., Calleja-Gonzalez, J., & Leicht, A. S. (2017). Cardiovascular and perceptual stress of female basketball referees during women's International matches. *Journal of Sports Medicine and Physical Fitness*, *57*(4), 476-482. doi:10.23736/S0022-4707.16.06230-7
Weston, M., Bird, S., Helsen, W., Nevill, A., & Castagna, C. (2006). The effect of match standard and referee experience on the objective and subjective match workload of English Premier League referees. *Journal of Science and Medicine in Sport*, *9*(3), 256-262. https://doi.org/10.1016/j.jsams.2006.03.022
Weston, M., Castagna, C., Impellizzeri, F. M., Bizzini, M., Williams, A. M., & Gregson, W. (2012). Science and medicine applied to soccer refereeing. *Sports medicine*, *42*(7), 615-631. https://doi.org/10.2165/11632360-000000000-00000
Whaley, M. H., Kaminsky, L. A., Dwyer, G. B., Getchell, L. H., & Norton, J. A. (1992). Predictors of over-and underachievement of age-predicted maximal heart rate. *Medicine and Science in Sports and Exercise*, *24*(10), 1173-1179. https://doi.org/10.1249/00005768-199210000-00017

Número de citas totales / Total references: 52 (100%)
Número de citas propias de la revista/Journal'sownreferences: 1 (1,92%)

Rev.int.med.cienc.act.fís.deporte - vol. 22 - número 87 - ISSN: 1577-0354