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ORIGINAL

ACELT AND PLAYER LOAD: TWO VARIABLES TO QUANTIFY NEUROMUSCULAR LOAD

ACELT Y PLAYER LOAD: DOS VARIABLES PARA LA CUANTIFICACIÓN DE LA CARGA NEUROMUSCULAR

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CONFLICT OF INTERESTS

The last author of this article is an advisor in the area of Sports Science in the company responsible for the development of the inertial device used. To guarantee the objectivity of the results, this author has not contributed to the data analysis nor to the results section, but he has contributed significantly to other parts of the manuscript. The authors certify that this study has not been published or is in the process of being considered for publication in another journal, accepting the publication rules of the Journal.

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ABSTRACT

The objectives of this study were: (i) describe the dynamics of Player Load and AcelT and (ii) analyze the neuromuscular load in different anatomical locations (scapulae, center of mass, knee and ankle) in an incremental test in treadmill. Twenty-three semiprofessional male football players participated voluntarily in this research (age: 22.56±4.8 years; body mass: 75.5±5.5 kg; height: 1.79±0.5 m). Four WIMUPRO^{TM} inertial devices were utilized for recording both variables. The main results indicated that: (1) exists a nearly perfect relation between both variables (r>0.931), (2) the highest values were in knee (PL_{RT} = 8.01±2.76; AcelT = 2.70±.50) and in ankle (PL = 7.85±2.27; AcelT = 2.87±.49) and (3) a great variability was found between athletes. In conclusion, Player Load and AcelT are two valid variables to analyze and quantify neuromuscular demands.

KEYWORDS: accelerometry, football, performance, AcelT, Player Load.

RESUMEN

Los objetivos de esta investigación son: (i) describir el comportamiento de las variables Player Load y AcelT y (ii) cuantificar la carga neuromuscular en diferentes puntos anatómicos (espalda, centro de masas, rodilla y tobillo) durante un test incremental en rampa en tapiz rodante. Veintitrés jugadores semiprofesionales de fútbol varones participaron voluntariamente en este estudio (edad: 22,56±4,8 años; masa corporal: 75,5±5,5 kg; altura: 1,79±0,5 m). Ambas variables se registraron empleando 4 dispositivos inerciales WIMU PRO^{TM}. Los principales resultados indican que: (1) existe una correlación casi perfecta entre ambas variables (r=0,931), (2) los mayores valores en ambas variables se han encontrado en la rodilla (PL = 8,01±2,76; AcelT = 2,70±0,50) y el tobillo (PL = 7,85±2,27; AcelT = 2,87±0,49) y (3) existe una amplia variabilidad intersujeto. En conclusión, Player Load y AcelT son dos indicadores válidos para el análisis y cuantificación de las demandas neuromusculares.

PALABRAS CLAVE: acelerometría, fútbol, rendimiento, AcelT, Player Load.

1. INTRODUCTION

Among outdoor team sports, football is one of the most popular, both in the number of players and fans. This aspect has caused this sport modality to be one of the most studied in scientific literature (Sánchez, Yagüe, Fernández and Petisco, 2014). The current problem is that the great complexity of this sport has meant that the research carried out has not completely reduced the uncertainty surrounding training strategies for improving performance (Aguiar, Botelho, Lago, Maças and Sampaio, 2012).

In terms of physical and physiological demands, football is considered a team sport involving intermittent efforts of high intensity (McMillan, Helgerud, Macdonal and Hoff, 2005), in which a large number of short sprints, rapid accelerations, decelerations, turns, jumps, kicks and tackles are performed. Thus, a full recovery between actions in many cases is not possible (Arnason et al, 2004). All these dynamic and unpredictable technical-tactical actions, which vary in duration and intensity (Bloomfield, Polman and O'Donoghue, 2007), constitute the total internal and external load that players experience (Akubat, Barrett and Abt, 2014) and pose an energy challenge for them (Stølen, Chamari, Castagna and Wisløff, 2005). Accurate and objective quantification of the activities performed by players is fundamental to understanding the physical demands of football (Bradley, Di Mascio, Peart and Olsen, 2010, Dwyer and Gabbett, 2012, Johnston et al., 2012), since up to 1,350 different actions performed by the players have been recorded (Mohr, Krustrup and Bangsbo, 2003).

In order to improve the preparation methods, it is necessary to expand scientific knowledge. Therefore, an objective analysis of the characteristics of the game in competitive situations is required (Carling, Williams and Reilly, 2006). This possibility is, in large part, enabled by technological development and the authorisation of FIFA (International Federation of Association Football), for the use of electronic devices in competitive situations (FIFA, 2018). These investigations are providing new evidence in the study of physical and tactical demands (Castellano and Casamichana, 2014). Being aware of the requirements of the competition allows us to control training loads more effectively (Grehaigne, Godbout, and Zerai, 2011) and to improve the design of training tasks both physically (Gómez-Carmona, Gamonales, Pino-Ortega and Ibáñez, 2018) and tactically (Reche-Soto, Cardona, Díaz, Gómez-Carmona and Pino-Ortega, 2018b).

Monitoring the loads of team sports players is a common practice in both training and competition (Rogalski, Dawson, Heasman and Gabbett, 2013). The recording of the parameters is used by sports professionals in order to provide an explanation for possible changes in the performance of the athlete or to try to reduce the risk of injury, illness or training overload (Halson, 2014). The heterogeneous nature of each athlete's response to this training load makes their individualised analysis fundamental (Brink, Nederhof, Visscher, Schmikli and Lemmink, 2010, Paulson, Mason, Rhodes and Goosey-Tolfrey, 2015).

Considering the nature of the workload, it is classified as internal or external, both in the sports and scientific fields (Bartlett, O'Connor, Pitchford, Torres-Ronda and Robertson, 2017, Costa et al., 2013). Internal load refers to the psychological and physiological stress resulting from training-competition, while the external load includes the work done by the athlete in terms of distance, speed and acceleration (Lambert and Borresen, 2010; McLaren, Weston, Smith, Cramb and Portas, 2016; Paulson et al., 2015). In team sports, there is greater difficulty in evaluating the internal load (Borresen and Lambert, 2009), which has meant that the quantification of external load has undergone greater development in recent years.

Accelerometers were introduced in the 1950s (Culhane, O'Connor, Lyons, and Lyons 2005), and have evolved technologically to offer sufficient quality and reliability with a low production cost. They allow us to quantitatively evaluate human movement with a fully portable device. (Lemoyne, Coroian, Mastroianni and Grundfest, 2008). The multifunctional conception of inertial devices (Inertial measurement units, IMUs) is increasingly used in the sports context. These devices include different sensors such as accelerometers, gyroscopes, magnetometers, GNSS, etc. (Akenhead and Nassis, 2016; Boyd, Ball and Aughey, 2013; Gabbett, 2015).

One of the most commonly used load indicators, based on the accelerometer signal, is the PlayerLoad^{TM} (PL) variable (Barrett et al., 2016, Bradley et al., 2010, Dalen, Jørgen, Gertjan, Havard and Ulrik, 2016; Reche-Soto et al., 2019a), also known as Body Load (Gomez-Piriz, Jiménez-Reyes and Ruiz-Ruiz, 2011), depending on the inertial device used. This indicator is the combination of the accelerations produced in the three anatomical planes of movement, producing an estimate of the total load (Cummins, Orr, O'Connor and West, 2013), expressed in arbitrary units (Barrett et al., 2016). The PL has been proved to be a reliable and valid indicator (Hollville, Couturier, Guilhem and Rabita, 2016), which has a high correlation with physiological variables such as heart rate and VO2max (Barrett et al., 2016), and subjective scales of perception of effort (Casamichana, Castellano, Calleja-Gonzalez, San Román and Castagna, 2013). In addition, this variable has obtained high inter- and intra-device test-retest reliability in cyclical (Barrett et al., 2016) and acyclic activities (Boyd et al., 2013) as well as in multidirectional tasks (ICC = 0.806-0.949) (Barreira et al., 2017).

For all of the above, the objectives of this study were: (i) to describe the dynamics of the neuromuscular load variables Player Load and AcelT in an incremental treadmill ramp test and (ii) to quantify the neuromuscular load at different anatomical points (back, lumbar area, knee and ankle) during this test.

2. METHOD

2.1. PARTICIPANTS

Twenty-three semi-professional football players from a national football league (Third Division, Group XIII) voluntarily participated in this study (Age: 22.56 ± 4.8 years, Weight: 75.5 ± 5.5 kg, Height: 1.79 ± 0.5 metres). All participants had to meet the following requirements: (i) have more than two years of experience in football practice at a national level, (ii) present more than one year of experience with advanced technological monitoring in both training and official matches and (iii) not present any musculoskeletal injury or health problems that prevented their evaluation.

The study was approved by the ethics committee of the University of Murcia before the start (registration number 2061/2018), in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki, 2013).

Participants were previously informed of the details of the investigation and its possible risks and benefits, and gave their informed consent.

2.2. VARIABLES

- *Player Load (PL):* Accelerometer-derived measurements of total body load in its 3 axes (vertical, anterior-posterior and medial-lateral) have been used to evaluate the neuromuscular load in different athletes (Gómez-Carmona, Pino-Ortega, Sánchez-Ureña, Ibáñez, y Rojas-Valverde, 2019b; Reche-Soto et al., 2019b). It is represented in arbitrary units (a.u.) and is calculated from the following equation at a 100 Hz sampling frequency where: PL_n is the player load calculated in the current instant; *n* is the current instant in time; *n-1* is the previous instant in time; X_n, Y_n and Z_n are the values of Body Load for each axis of movement in the current instant in time; X_{n-1}, Y_{n-1} and Z_{n-1} are the values of Body Load for each axis of movement in the previous instant in time.

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

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

- AcelT: it is the magnitude of acceleration or resulting vector (Waldron, Twist, Highton, Worsfold, and Daniels, 2011) identified as the vector sum of the total acceleration recorded by the accelerometer, which is the result of gravity (y axis), changes in horizontal movement (x axis) and forces related to the rotation movements (z-axis) of a body segment or object to which the accelerometer is attached (O'Donovan, Kamnik, O'Keeffe and Lyons, 2007, Kunze, Bahle, Lukowicz and Partridge, 2010). It is calculated from the following formula:

$$Resultant\ vector\ (AcelT) = \sqrt{x^2 + y^2 + z^2}$$

2.3. INSTRUMENTS

Anthropometric characteristics

The height of the subjects was measured with a wall-mounted height meter during full inhalation (SECA, Hamburg, Germany), and body weight was obtained using a body composition monitor, model BC-601 (TANITA, Tokyo, Japan).

Neuromuscular load

Both variables were recorded using 4 WIMUPRO^{TM} inertial devices (RealTrack Systems, Almeria, Spain), which contain four triaxle accelerometers that detect and measure movement using an electromechanical system with a sampling frequency from 10 to 1,000 Hz. The motion detection range is ± 16 g, ± 16 g, ± 32 g and ± 400 g. Each device has its own 1 GHz microprocessor, 8 GB of internal memory and high-speed USB output to record, store and download data. Each device has an internal battery with a duration of more than 4 hours, weighing 70 g and measuring 81 × 45 × 16 mm. In this study, the accelerometers were configured to record the research variables with a sampling frequency of 1,000 Hz.

The devices were placed on the: (i) back (C6, between the scapulae), (ii) lumbar region (L3, at the height of the centre of mass) (McGregor, Armstrong, Yaggie, Parshad and Bollt, 2011), (iii) knee (5 cm above the crack of the kneecap) and (iv) ankle (5 cm above the lateral malleolus). The devices were placed on the outside part of the right leg in all subjects, both on the ankle and knee.

Prior to their placement, the devices were calibrated and synchronised. Thanks to this process, the accelerometers eliminate the 4 sources of error that may occur: displacement error, scaling error, orthogonal errors and random error (Wang, Liu and Fan, 2006). The device calibration process was carried out following the manufacturer's recommendations in the auto-start process. To ensure proper functioning, three aspects had to be met: (a) leaving the device immobile for 30 seconds, (b) on a flat surface and (c) without close contact with magnetic devices (Bastida-Castillo, Gómez-Carmona, Reche, Granero-Gil and Pino-Ortega, 2018). Following this procedure, the accelerometers in this device have obtained very high reliability values in static and dynamic tests in different anatomical locations (Gómez-Carmona, Bastida-Castillo, García-Rubio, Ibáñez and Pino-Ortega, 2019a).

Figure 1 shows the location of the inertial devices, which were placed as follows: (i) back, using a specific harness anatomically adjusted to the subject and (ii) L3, ankle and knee, using an extendable band that was attached to the subject with Velcro and finally sealed with adhesive tape in order to reinforce the fastening.

Figure 1. Location of the inertial devices in the study participants.

2.4. PROCEDURE

The study was carried over 2 weeks, with a total of 3 sessions. In the first session, anthropometric measurements were recorded and both the protocol and the objective of the study were explained. The second session consisted of familiarisation with the test and running using technological monitoring. In the third session, the incremental ramp test was performed on a treadmill. The starting speed was 8 km / h. From the beginning, a continuous speed increase of 0.1 km / h was made every 12 seconds (1 km / h every 2 minutes). The test ended when the subject could not maintain the speed.

All sessions began at 9:00 am and the subjects had to meet the following requirements: (i) suppression of alcohol and caffeine intake 24 hours before each session and (ii) not performing high intensity physical activity the 48 hours prior to the completion of the protocol; so that none of these factors interfered in the investigation (Billat, 2002, Spriet, 2014).

Before carrying out each of the protocols, a standardised warm-up of 5 minutes of continuous running was performed at 65% of HRmax, which was monitored and controlled in real time by sending data from the WIMUPRO^{TM} inertial devices (RealTrack Systems, Almeria, Spain) using Wi-Fi technology to a computer which had the software SPRO^{TM} (RealTrack Systems, Almeria, Spain) to check the perfect functioning of the devices (Bastida-Castillo, Gómez-Carmona and Pino-Ortega, 2016). At the end of the protocol, subjects performed 5 minutes of continuous running at 55% of the HRmax.

3. STATISTICAL ANALYSIS

The Shapiro-Wilk test was used to determine the distribution of the data, and for the homoscedasticity the Levene test was applied (Field, 2013). The analysis showed a normal distribution, so parametric tests were used. First a descriptive analysis was made showing the results in terms of average and standard deviation. A linear regression was performed to determine the cause-effect relationship between the two neuromuscular load variables Player Load and AcelT depending on the location of the inertial devices, the subjects involved and the running speed. The statistical tests were performed using the software SPSS 24.0 (SPSS Inc., Chicago IL, USA). The statistical significance was established with the value of $p < 0.05$.

4. RESULTS

Table 1 presents the descriptive analysis of the neuromuscular load variables AcelT and Player Load in the different locations and according to the different running speeds. Higher values are found in both variables the higher the running speed. In addition, values also increase as the location is closer to the point of contact of the foot with the ground.

Table 1. *Descriptive analysis of neuromuscular load variables.*

Speed (km/h)	Player Load								AcelT							
	Back		L3		Knee		Ankle		Back		L3		Knee		Ankle	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
8	2.26	0.35	2.37	0.42	4.90	0.63	4.81	0.82	1.19	0.04	1.30	0.06	2.05	0.09	2.13	0.10
8,5	2.34	0.40	2.51	0.43	5.26	0.67	5.12	0.67	1.20	0.04	1.32	0.06	2.14	0.09	2.22	0.10
9	2.46	0.43	2.66	0.42	5.65	0.70	5.60	0.70	1.22	0.04	1.34	0.06	2.22	0.09	2.33	0.09
9,5	2.51	0.44	2.80	0.44	6.02	0.77	5.97	0.68	1.23	0.04	1.36	0.07	2.30	0.10	2.43	0.10
10	2.60	0.44	2.94	0.46	6.45	0.82	6.38	0.73	1.25	0.04	1.38	0.07	2.39	0.10	2.53	0.09
10,5	2.70	0.46	3.08	0.47	6.80	0.90	6.74	0.75	1.26	0.04	1.40	0.08	2.46	0.11	2.62	0.10
11	2.80	0.45	3.22	0.46	7.44	1.55	7.08	0.83	1.27	0.04	1.42	0.08	2.59	0.22	2.72	0.10
11,5	2.91	0.44	3.34	0.45	7.91	1.79	7.57	0.83	1.28	0.04	1.44	0.08	2.68	0.25	2.82	0.10
12	3.00	0.47	3.49	0.44	8.32	1.93	7.96	0.83	1.29	0.04	1.45	0.08	2.76	0.27	2.92	0.10
12,5	3.11	0.46	3.63	0.47	8.76	2.08	8.46	0.84	1.30	0.04	1.47	0.09	2.85	0.30	3.04	0.11
13	3.21	0.48	3.72	0.46	9.25	2.13	8.93	0.93	1.32	0.04	1.48	0.09	2.94	0.31	3.15	0.12
13,5	3.30	0.46	3.87	0.47	9.78	2.29	9.46	1.04	1.33	0.04	1.50	0.08	3.05	0.36	3.25	0.13
14	3.47	0.51	3.93	0.43	10.53	3.00	9.99	1.06	1.34	0.04	1.51	0.08	3.22	0.53	3.36	0.12
14,5	3.55	0.49	4.09	0.44	11.40	4.00	10.54	1.16	1.36	0.05	1.52	0.08	3.37	0.67	3.47	0.12
15	3.56	0.47	4.16	0.46	10.82	1.79	11.23	1.26	1.37	0.05	1.54	0.09	3.24	0.12	3.61	0.12
15,5	3.75	0.44	4.40	0.52	10.93	1.41	11.79	1.21	1.39	0.06	1.57	0.09	3.31	0.11	3.72	0.14
16	3.73	0.30	4.58	0.27	11.68	0.78	12.68	1.06	1.37	0.03	1.59	0.12	3.44	0.04	3.94	0.07
Total	2.94	0.63	3.37	0.75	8.01	2.76	7.85	2.27	1.28	0.07	1.43	0.11	2.70	0.50	2.87	0.49

Nota. *M: mean; SD: Standard deviation.*

Figure 2 shows the regression analysis between the variables Player Load and AcelT during the incremental running test in all the subjects analysed. There are different dynamics between the upper body load and the lower body load along the speed spectrum. As a whole, there is a nearly perfect correlation between both neuromuscular load variables ($R^2 = 0.931$).

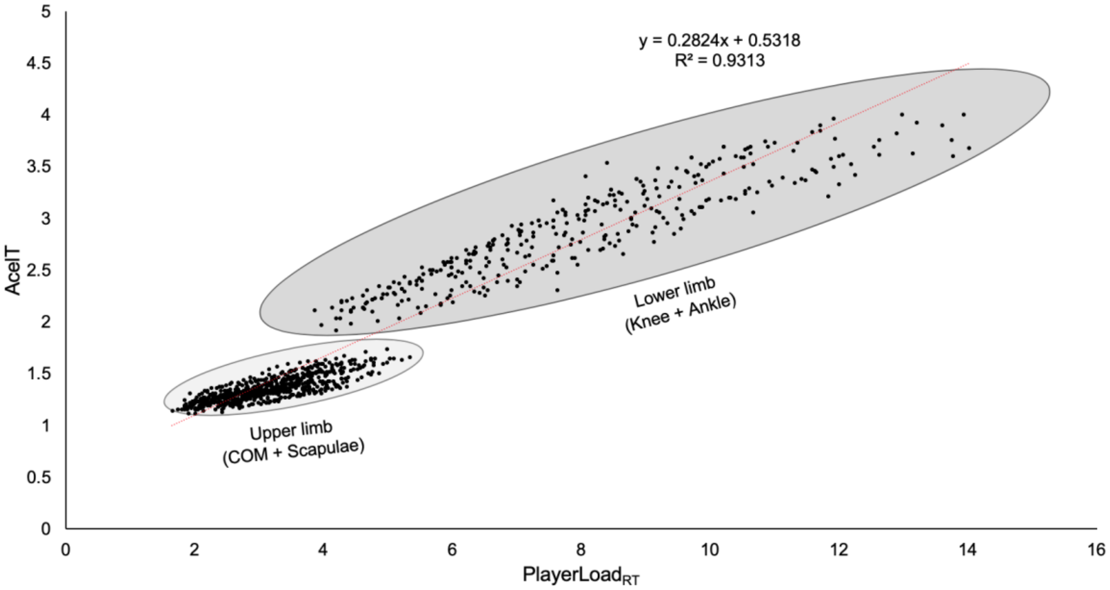

Figure 2. *Graphical representation of the relationship between the variables Player Load and AcelT during the progressive incremental test on the treadmill.*

Table 2 shows the linear regression between the neuromuscular load variables AcelT and Player Load in each of the subjects analysed in the different locations. We find an inter-subject variability in the location analysis. In addition, we find the best relationships in the ankle ($R^2 = 0.956$) and the knee ($R^2 = 0.916$) both individually and globally. Both locations belong to the neuromuscular load dynamics of the lower body.

Table 2. *Linear regression between the variables of neuromuscular load Player Load and AcelT in the different locations analysed in each of the study participants.*

Participants	Locations			
	Ankle	Knee	L3	Back
1	0.997	0.958	0.998	0.973
2	0.982	0.996	0.980	0.970
3	0.992	0.993	0.992	0.947
4	0.992	0.993	0.992	0.947
5	0.990	0.998	0.980	0.941
6	0.997	0.999	0.990	0.964
7	0.996	0.984	0.992	0.967
8	0.993	0.990	0.973	0.989
9	0.996	0.996	0.988	0.956
10	0.996	0.998	0.984	0.923
11	0.987	0.996	0.954	0.988
12	0.998	0.993	0.987	0.976
13	0.993	0.979	0.997	0.987
14	0.998	0.999	0.997	0.988
15	0.990	0.998	0.997	0.986
16	0.992	0.997	0.956	0.955
17	0.995	0.988	0.956	0.952
18	0.987	0.987	0.949	0.990
19	0.990	0.994	0.962	0.978
20	0.989	0.998	0.956	0.987
21	0.996	0.992	0.993	0.952
22	0.995	0.998	0.998	0.887
23	0.995	0.996	0.980	0.973
Total	0.956	0.916	0.765	0.713

Finally, Table 3 presents a relational analysis of the neuromuscular load variables Player Load and AcelT in the different locations according to the running speed. Better relationships are found when the speeds are higher in the aforementioned locations, ankle and knee.

Table 3. *Linear regression between the neuromuscular load variables Player Load and AcelT in the different locations analysed according to the running speed.*

Speed	Locations				Total
	Ankle	Knee	L3	Back	
8	0.806	0.628	0.520	0.139	0.879
8.5	0.606	0.646	0.514	0.276	0.900
9	0.590	0.577	0.531	0.331	0.910
9.5	0.545	0.478	0.555	0.361	0.913
10	0.535	0.440	0.551	0.424	0.916
10.5	0.549	0.407	0.559	0.429	0.916
11	0.765	0.789	0.513	0.469	0.906
11.5	0.789	0.834	0.524	0.421	0.909
12	0.847	0.834	0.543	0.394	0.908
12.5	0.820	0.847	0.563	0.464	0.912
13	0.817	0.841	0.566	0.550	0.915
13.5	0.817	0.835	0.462	0.462	0.921
14	0.907	0.904	0.420	0.546	0.935
14.5	0.928	0.920	0.396	0.495	0.924
15	0.786	0.676	0.379	0.494	0.928
15.5	0.780	0.608	0.541	0.512	0.933
16	0.781	0.897	0.567	0.549	0.972

5. DISCUSSION

The objectives of this study were: (i) to describe the dynamics of the neuromuscular load variables Player Load and AcelT and (ii) to quantify such demands in different anatomical locations along the speed spectrum during an incremental treadmill ramp test.

In the descriptive analysis performed, the highest values in the Player Load and AcelT variables were found in the knee (PL = 8.01 ± 2.76, AcelT = 2.70 ± 0.50) and the ankle (PL = 7, 85 ± 2.27, AcelT = 2.87 ± 0.49), the values in both variables increasing as the running speed increased. The contribution of the load from individual planes can also be influenced by the anatomical position of the accelerometer. Barrett, Midgley and Lovell (2014) find that the values of both variables in the locations which are closest to the point of contact of the foot with the ground increase as the speed increases. However, it is generally accepted that the centre of mass (lumbar area, L3) (McGregor et al., 2011) is the optimal anatomical location for the placement of these devices (Halsey, Shepard and Wilson, 2011; McGregor, Busa, Yaggie and Bollt, 2009), although, as in our case, there are exceptions in the literature (Boyd et al., 2013, Scott, Black, Quinn and Coutts, 2013, Cormack et al., 2013). Specifically, in the study conducted by Barrett et al., (2014) where the registered PL was slightly higher in L3 than in the back.

As for the regression analysis performed between the accelerometric load variables Player Load and AcelT, it is shown that both variables have a nearly perfect correlation (r> 0.931). Therefore, both variables are valid for the quantification and analysis of neuromuscular demands. The PL has been accepted as a valid indicator to interpret the amount of external load experienced by a player in different sports such as football (Barreira et al., 2017, Casamichana et al., 2013, Scott et al., 2013), Australian football (Boyd et al., 2013; Gastin, McLean, Spittle and Breed, 2013; Scott et al., 2013) and linear running (Barrett et al., 2014). Previous research has shown significant and strong relationships between neuromuscular load measurements and the ratio of injuries in rugby players (Gabbett, 2004a, Gabbett 2004b), so both variables are put forward as indicators of injury risk in team sports. The PL also presents a high relation with respect to the Edwards index (r = 0.70), the subjective perception of effort (PSE) (r = 0.74) and with the volume of movement through the total distance travelled variable (r = 0.70) (Casamichana et al., 2013). Scott et al. (2013) also found a strong relationship between the PL variable and the Edwards index (r = 0.80). In short, the studies show that the PL is a valid indicator to quantify the demands in football, being acceptable for use in competition (CV = 1.9%) (Boyd et al., 2013).

The linear regression between the neuromuscular load variables AcelT and Player Load in each of the subjects analysed in the different locations shows an inter-subject variability in the location analysis. In addition, we found the best relationships in the ankle (R^2 = 0,956) and knee (R^2 = 0,916), both individually and globally. Such relationships are higher at a higher running speed. The results obtained are linked to those found in the research conducted by Nedergaard et al. (2017) where there is a low correlation between the acceleration of the centre of mass (L3) and the rest of locations (tibia, knee and scapula) concluding that the acceleration of the whole body cannot be detected by placing an accelerometer in the centre of mass due to the complexity of sports actions. Therefore, to achieve the best accuracy, the ideal location would be the ankle / tibia because it is the first joint point that receives more directly the forces that the subject exerts against the ground while running, obtaining a high validity with respect to force platforms (Raper et al., 2018) and detecting differences in impact depending on the type of footwear (Sinclair and Sant, 2017).

6. LIMITATIONS OF THE STUDY

Different limitations must be taken into account when interpreting the results obtained in this investigation. Firstly, the number of participants is small (n = 23), which may influence the statistical power of the results analysed. Secondly, the participants analysed were national level male football players, so the results could not be extrapolated to other study populations. Finally, only four inertial devices at a specific sampling frequency were used for the data collection. The components of the inertial devices, the calibration of the sensors and the sampling frequency can affect the results obtained. Therefore, the recording of the data through the inertial devices was carried out following the manufacturer's recommendations.

7. CONCLUSIONS

Player Load and the AcelT are two valid indicators for the analysis and quantification of neuromuscular demands. Therefore, both indicators can be used interchangeably to quantify neuromuscular load in training and competition. The lower limb supports greater neuromuscular load with respect to the upper limb, therefore, it is necessary to analyse its dynamics to adapt training loads and recovery protocols. Finally, there is wide inter-subject variability, which is why an individualised load analysis is recommended for greater specificity with the aim of improving sports performance.

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