RICYDE. Revista Internacional de Ciencias del Deporte
doi: 10.5232/ricyde
Rev. Int. cienc. deporte

RICYDE. Revista Internacional de Ciencias del Deporte
Volume XVIII - Year XVIII
Pages: 43-53 - ISSN: 1885-3137
Issue 67 - January 2022

https://doi.org/10.5232/ricyde2022.06704

The Relationship between External and Internal Load during Elite Pre-season Friendly Basketball Games

La relación entre la carga externa y la carga interna durante partidos amistosos en baloncesto de élite

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Abstract

The aim of this study was to analyse the relationship between External Load (EL) and internal load (IL). Thirteen male basketball players competing at professional level in First Spanish Division (ACB) during six friendly games throughout the 2020/2021 preseason were monitored. The EL variables collected were movement load (ML), movement intensity (MI), box score time (BST), and total duration (TD)] while IL variables monitored were heart rate (HR), respiratory rate (RR), training impulse (TRIMP) and time invested in five HR zones. Very large to almost perfect correlation (r= 0.77-0.91) exists between EL variables except TD. In addition, HR, TRIMP and RR present large to very large correlation (r= 0.55-0.79) with all EL variables except TD. Monitoring HR-based variables would present general information and an estimated prediction of players EL which could allow basketball practitioners to prioritize time invested players internal/external load.

Keywords: Training load; load monitoring; heart rate; TRIMP

Resumen

El objeto de este estudio fue analizar la relación entre la Carga Externa (EL) y la Carga Interna (IL) durante partidos de baloncesto. Trece jugadores profesionales de la primera división Española(ACB) fueron monitorizados durante 6 partidos amistosos a lo largo de la pretemporada 2020/2021. Las variables de carga externa recogidas fueron carga de movimiento (ML) intensidad de movimiento (MI), tiempo de marcador (BST) y duración total (TD), mientras que las variables de carga interna monitorizadas fueron Frecuencia Cardíaca (HR), Frecuencia Respiratoria (RR), Impulso de Entrenamiento (TRIMP) tiempo invertido en cinco zonas cardíacas. Existe una alta correlación a casi perfecta (r= 0.77-0.91) entre las variables de EL except TD. Además, HR, TRIMP y RR presentan una alta a muy alta correlación (r= 0.55-0.79) con todas las variables de EL excepto TD. Monitorizar variables basadas en el HR puede aportar información general y estimar una predicción de la EL de los jugadores, lo que podría ayudar a los profesionales a priorizar el tiempo invertido en monitorizar la carga interna/externa.

Palabras Clave: carga de entrenamiento; monitorización de la carga; frecuencia cardíaca; TRIMP

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Received: August 11, 2021; Accepted: November 25, 2021

Introduction

The main objective during training is to try to prescribe the optimal training load (Aoki, Ronda, Marcelino, Drago, Carling, Bradley & Moreira, 2017) and stimulate specific adaptations (Aoki et al., 2017; Foster, Florhaug, Franklin, Gottschall, Hrovitan, Parker, Doleshal & Dodge, 2001) obtaining the desired response (Impellizzeri, Marcora, & Coutts, 2018), while improving athletic performance and reducing the risk of overtraining and injury (Aoki et al., 2017). Additionally, knowing the workload of the game and practices is vital when establishing optimal training procedures (Torres-Ronda, Ric, Llabres-Torres, De las Heras & Schelling, 2016).

The external training load (EL) is the load performed (e. g. duration, distance), which is determined by the organization, quality, and quantity of exercise (training plan) whilst internal load (IL) is defined as the psycho-physiological response during exercise to cope with the requirements elicited by the EL (e. g. heart rate (HR)) (Impellizzeri et al., 2018). According to these definitions, the concepts of external and internal load do not have a single or gold standard measure, but rather these may be quantified by a multitude of variables, which describe the EL or IL during the exercise (Impellizzeri et al., 2018). Many subjective (e.g. wellness questionnaires) and objective (e.g. HR) measures allow to quantify physiological and performance capacities, which may be used to guide training prescription (Saw, Main & Gastin, 2016).

Monitoring and combining the EL and the IL, during both practices and games, is considered as crucial in determining optimal training methods. Several training load monitoring tools can be utilized to control EL (e. g. time motion analysis, global and local positional systems (GPS/LPS), inertial movement units (IMUs) and IL (e. g. HR devices) (Portes, Navarro, Sosa, Trapero & Jiménez, 2019; Reina, García-Rubio, Antúnez, Courel-Ibáñez & Ibáñez, 2019; M.T.U, Scott, T.J, Scott & Kelly, 2016). Associations between IL and EL are important in understanding the dose–response nature of team-sport training and competition as well as to select the crucial variables to monitor (Impellizzeri et al., 2018). Thus, it is important to know the relationship between workload variables (EL vs IL, EL vs EL and IL vs IL) in order to identify key performance variables for efficient load monitoring framework.

Consequently, there are previous studies in team sports such as soccer (Gómez-Carmona, Pino-Ortega, Sánchez-Ureña, Ibáñez & Rojas-Valverde, 2019; Rago, Brito, Figueiredo, Krustrup & Rebelo, 2019), Australian football (Bartlett, O'Connor, Pitchford, Torres-Ronda & Robertson, 2017) or basketball (Fox, O'Grady, & Scanlan, 2020; Reina et al., 2019; Scanlan, Wen, Tucker & Dalbo, 2014; Svilar & Jukić, 2018) that analyzed the within-subject correlations between EL and IL (Bartlett et al., 2017; Rago et al., 2019; Scanlan et al., 2014; Svilar & Jukić, 2018). Novel findings in basketball revealed significant correlation (range r=0.71–0.93) between session rate perceived exertion (sRPE) and external load variables (player load, accelerations, decelerations and change of directions) (Svilar & Jukić, 2018). Furthermore, significant moderate relationships were detected between EL (derived from accelerometer) and IL (sRPE (r42 = 0.49) and Training IMPulse (TRIMP) models (r42 = 0.38) (Scanlan et al., 2014).

To date, studies investigating the relationship between EL and IL indicators in basketball have mainly used subjective internal variables (e.g. sRPE) (Fox et al., 2020; Scanlan et al, 2014; Svilar & Jukić 2018), however just one previous study carried out with eight semi-professional, male basketball players (Queensland basketball league, which is a second tier, state-level Australian basketball competition, has utilized HR (Scanlan et al., 2014). For the previous reasons mentioned, more studies in basketball analyzing the relationship between objective EL and IL are necessary. Consequently, further research in professional population is needed to determine correlation between variables, which will provide a more efficient scenario, where practitioners could avoid redundancy and select only crucial variables in training load monitoring process.

The aim of this study was to examine the within-player correlation between EL (movement load, movement intensity, box score time and total duration) and IL (Heart rate, respiratory rate, TRIMP) during the pre-season games in professional Spanish basketball league. Additionally, the second objective was to explore the relationship intra EL and IL variables (EL vs EL and IL vs IL). It was hypothesized that. correlation might be existing between variables (EL and IL; EL vs EL; IL vs IL).

Methods

Sample

Data has been collected from 13 male basketball players (mean ± SD: age 26.43 ± 4.59 years, height 196.53 ± 9.82 cm, body mass 97.88 ± 14.49 kg) competing at professional level (Swann, Moran & Piggott, 2015) in First Spanish Division (ACB) during six friendly games (5 wins/1 loss) throughout the 2020/2021 preseason (6 games in 33 days). The exclusion criteria followed throughout the study was, a minimum of five minutes box score time, where all players from the team that had less than five minutes per match, were excluded from that match, but not from the study. Additionally, all participants had to perform in at least fifty percent of the games (3/6 games). After the exclusion criteria had been applied, two participants were excluded from the analysis, resulting in data from 11 subjects being analyzed. Furthermore, every participant received detailed in-formation on the purpose of the investigation and the study was in accordance to the Declaration of Helsinki (Harriss, Macsween & Atkinson, 2019).

Procedures

During each game, each player wore a Firstbeat TeamBelt from FirstBeat SPORTS Team Pack (Firstbeat Technologies Ltd., Jyväskylä, Finland) which is a chest belt attached to the ribcage under the musculus pectoralis major; it contains two built-in electrodes and a wireless unit that transmits data in real time to a receiver connected to a computer. This 9-axis motion sensor is a lightweight (10g including battery), swim and shock proof sensor, which collects data at 50 Hz frequency. All players were familiar with the technology, as they have been using these bands in every practice session of the previous season, prior to when the study data collection started. Each Firstbeat, which has proved to be a valid and reliable system for long term monitoring of heart rate, respiratory rate, and heart rate variability (Bogdány, Boros, Szemerszky & Köteles, 2004) were turned on prior to each activity (immediately before the start of the game) and participants wore the same first beat throughout the study period to avoid inter-sensor variation athletes. After each game, data was extracted from the Firstbeat Sports software (version 1.23.0) onto a Microsoft Excel (version 16.0, Microsoft Corporation, Redmond, WA) spreadsheet for further analysis.

Variables

The parameters recorded were classified in (I) external load variables, and (II) internal load variables.

External Load variables:

–*Box score time (BST):* The time in minutes that each player invests on the court during the game, excluding all stoppages in play such free-throws, faults, out-of-bounds, break periods between quarters, time-outs, or time that the players were substituted out of the game.

–*Total duration (DUR):* The all-time from the beginning of the game until the end, including all stoppages in play such as free-throws, faults, out-of-bounds, break periods between quarters, time-outs, or time that the players were substituted out of the game (benching time).

–*Movement Load (ML):* This parameter considers all of an athlete's accelerations in three-dimensional planes using the following formula:

$$ML = \sqrt{\frac{\left(a_{y1} - a_{y-1}\right)^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{300}}$$

–*Movement Intensity (MI):* The average ML per minute.

<u>*Internal Load variables*</u>**:**

–*Heart Rate (HR):* The average of heart rate measured in beats per minute (bpm).

–*Respiratory rate (RR):* The number of respirations per minute.

–*TRIMP:* The TRIMP formula in Firstbeat Sports is based on Banister's original TRIMP calculation with some modifications. Instead of using the mean heart rate across a session, Firstbeat uses beat-to-beat heart rate data, which has been proved as a more reliable method to determine it (Berkelmans, Dalbo, Kean, Milanović, Stojanović, Stojiljković & Scanlan, 2018). Firstbeat has also set a lower intensity limit for the TRIMP accumulation to ensure that TRIMP number is derived only from activity. The formula is (Scanlan et al., 2014):

$$TRIMP = T \times \left[\frac{(HR_{ex} - HR_{rest})}{(HR_{max} - HR_{rest})}\right] \times 0.64e^{1.92\left[\frac{(HR_{ex} - HR_{rest})}{(HR_{max} - HR_{rest})}\right]} \quad (1)$$

Notes: T = Duration; HR_{ex} = Hear rate during workout; HR_{rest} = resting heart rate; HR_{max} = maximal heart rate; e = ~2,718.

Time invested in five different hear rate zones: The time spent in each different intensity HR zones. The maximum HR is based on 220 – age in years while the minimum heart rate was calculated before each activity where every player had to stay steady and lay down for 3 minutes. (Achten & Jeukendrup, 2003; Berkelmans et al., 2018) The zones selected were classified into the following five relative HR thresholds (Table 1).

Table 1. Relative HR thresholds.

HR Zone	% Heart Rate	bpm
Zone 1: Recovery	<60	<115
Zone 2: Aerobic zone 1	60-69.9	115-134
Zone 3: Aerobic zone 2	70-79.9	135-152
Zone 4: Anaerobic threshold zone	80-89.9	153-172
Zone 5: High intensity training.	>90	>172

An important methodological aspect that must be considered is that all parameters (less BST and TRIMP) are based on DUR which means that values are conditioned by the time from the beginning of the game to the final, including all stoppages in play such as free-throws, faults, out-of-bounds, break periods between quarters (including half-time), time-outs, or benching time (e.g. heart rate con-siders the bpm taking in to account the time a player is playing, benching or during the break time).

Statistical Analysis

Mean ± standard deviation (SD) and the coefficient of variation (CV %) were calculated for all physical variables (BST, DUR, ML, MI, HR, RR, TRIMP and Time invested in five different heart rate zones). Moreover, Kolmogorov-Smirnov normality test was conducted to define normal distribution. Spearman's correlation test with 95% coefficient intervals was used to analyse the relationship between variables (EL and IL; EL vs EL; IL vs IL). Kolmogorov-Smirnov normality test showed how variables are not normally distributed. Therefore, as Spearman's Correlation coefficient is more robust to outliers than Pearson's correlation coefficient, Spearman's correlation was performed (Mukaka, 2012). They were qualitatively interpreted using the following criteria: trivial ($r \leq 0.1$), small ($r = 0.1–0.3$), moderate ($r = 0.3–0.5$), large ($r = 0.5–0.7$), very large ($r = 0.7–0.9$) and almost perfect ($r \geq 0.9$) (Hopkins, Marshall, Batterham & Hanin, 2009). Otherwise, the correlation was interpreted as the observed magnitude. Significance was set at $p < 0.05$. All analyses were conducted using IBM SPSS for Windows (version 23, IBM Corporation, Armonk, New York).

Results

Descriptive values such as mean and ±SD of all variables included in the study are revealed in Table 2. Moreover, Kolmogorov-Smirnov normality test and % CV test are also presented in table 2. Spearman's correlation test with 95% coefficient intervals was used to analyse the correlation that exists between variables and group of variables (EL vs IL; EL vs EL; IL vs IL) (Table 3).

Table 2. Descriptive analysis of all the external and internal load variables.

Variable	Mean ± SD	P-value of Kolmogorov-Smirnov	% CV
BST (min)	18.63 ± 6.02	.200*	32.3
DUR (min)	119.36 ± 7.70	.008	6.4
ML	218.76 ± 67.69	.200*	30.9
MI	1.96 ± 0.52	.200*	26.4
HR (bpm)	127.33 ± 104.30	.200*	81.9
RR (resp·min)	27.09 ± 3.15	.058	11.6
TRIMP	118.89 ± 38.14	.200*	32.0
Zone 1 (min)	101.81 ± 8.39	.200*	24.3
Zone 2 (min)	18.90 ± 8.39	.027	44.3
Zone 3 (min)	12.02 ± 5.44	.043	45.2
Zone 4 (min)	17.03 ± 7.50	.200*	44.0
Zone 5 (min)	8.91 ± 8.32	.001	93.3

Notes: (BST (min) = Box Score Time (min); DUR (min) = Total Duration (min); ML = Movement Load; MI = Average Movement Intensity; HR (bpm) = Average Heart Rate (bpm); RR (Resp·min) = Average Respiratory Rate (resp·min); Zone 1 (min) = Recovery; Zone 2 (min) = Aerobic zone 1; Zone 3 (min) = Aerobic zone 2; Zone 4 (min) = Anaerobic threshold zone; Zone 5 (min) = High intensity training; * lower bound of the true significance.).

Table 3. Spearman's correlation test with 95% coefficient intervals for all the external and internal load variables.

		BST	DUR	ML	MI	HR	RR	TRIMP	Zone 1	Zone 2	Zone 3	Zone 4
DUR (min)	r	0.01	—									
	p	.938	—									
ML	r	0.78**	0.07	—								
	p	.000	.618	—								
MI	r	0.81**	-0.10	0.91**	—							
	p	.000	.471	.000	—							
HR (bpm)	r	0.60**	0.05	0.57**	0.70**	—						
	p	.000	.703	.000	.000	—						
RR (Resp·min)	r	0.66**	-0.06	0.66**	0.80**	0.88**	—					
	p	.000	.653	.000	.000	.000	—					
TRIMP	r	0.52**	0.21	0.63**	0.54**	0.80**	0.63**	—				
	p	.000	.113	.000	.000	.000	.000	—				
Zone 1 (min)	r	-0.53**	0.33*	-0.45**	-0.56**	-0.67**	-0.60**	-0.54**	—			
	p	.000	.011	.000	.000	.000	.000	.000	—			
Zone 2 (min)	r	0.01	0.04	0.16	0.09	0.34**	0.16	0.55**	-0.45**	—		
	p	.946	.758	.245	.494	.010	.231	.000	.000	—		
Zone 3 (min)	r	0.62**	0.16	0.60**	0.52**	0.34**	0.27*	0.43**	-0.54**	0.30*	—	
	p	.000	.235	.000	.000	.008	.042	.001	.000	.021	—	
Zone 4 (min)	r	0.75**	0.02	0.80**	0.76**	0.41**	0.49**	0.39**	-0.29*	-00.17	0.46**	—
	p	.000	.868	.000	.000	.001	.000	.002	.027	.192	.000	—
Zone 5 (min)	r	0.05	0.13	0.08	0.08	0.63**	0.44**	0.74**	-0.31*	0.43**	-0.09	-0.19
	p	.721	.348	.530	.557	.000	.001	.000	.017	.001	.481	.160

Notes: BST (min) = Box Score Time (min); DUR (min) = Total Duration (min); ML = Movement Load; MI = Average Movement Intensity; HR (bpm) = Average Heart Rate (bpm); RR (Resp·min) = Average Respiratory Rate (times/min); Zone 1 (min) = Recovery; Zone 2 (min) = Aerobic zone 1; Zone 3 (min) = Aerobic zone 2; Zone 4 (min) = Anaerobic threshold zone; Zone 5 (min) = High intensity training) (*p<.05; **p<.01; ***p<.001).

Regarding to EL vs IL correlation analysis BST seems to have a strong correlation with HR (r: 0.60, p: 0.00; large), RR (r: 0.66, p: 0.00; large), TRIMP (r: 0.52, p: 0.00; large), zone 1 (r: -0.53, p: 0.00; large), zone 3 (r: 0.62, p: 0.00; large) and zone 4 (r: 0.75, p: 0.00; very large).

Related with the correlation of HR, RR, TRIMP and zone 1 with the other variables as well as between them. It is observable that HR has a strong correlation with all of the variables (BST = r: 0.60, p: 0.000; large, RR = r: 0.88, p: 0.000; very large, TRIMP = r: 0.80, r: 0.000; very large, zone 1 = r: -0.67, p: 0.000; very large, zone 2 = r: 0.34, p: 0.100 ; moderate, zone 3 = r: 0.34, p: 0.000; moderate, zone 4 = r: 0.41, p: 0.001; moderate, zone 5 = r: 0.63, p: 0.000; large).

RR also shows a strong correlation with BST (r: 0.66, p: 0.000; large), HR (r: 0.88, p: 0.000; very large), TRIMP (r: 0.63, p: 0.000; large), zone 1 (r: -0.60, p: 0.000; large). In turn, TRIMP appears to have high correlation values with all the variables (BST = r: 0.52, p: 0.000; large, HR = r: 0.80, p: 0.000; very large, RR = r: 0.63, p: 0.000; large, zone 1 = r: -0.54, p: 0.000; large, zone 2 = r: 0.55, p: 0.000; large; zone 5 = r: 0.74, p: 0.000; very large).

Furthermore, zone 2 expose substantive correlation with TRIMP (r: 0.55, p: 0.000; large) and zone 1 (r: -0.45, p: 0.000; large). Additionally, zone 3 shows moderate to large correlation with all the variables except DUR (r: 0.16, p: 0.235; small), RR (r: 0.27, p: 0.042; small) and Zone 5 (r: -0.09, p: 0.481; trivial). Finally, zone 5 presents large to very large correlations with HR (r: 0.63, p: 0.000; large), TRIMP (r: 0.74, p: 0.000; very large).

Discussion

The aim of the study was to analyze the within-player correlation between EL and IL. Moreover, this research also aims to explore the relationship intra EL and IL variables (EL vs EL and IL vs IL). To our knowledge, there are no previous studies that analyze the correlation of external load variables with objective internal load variables (HR) in elite basketball players, during games. However, there is previous research that analyses the relationship of external load variables with internal load (RPE) of elite basketball players during games-practices (Svilar & Jukić, 2018) or semi-professional players during games-practices (Fox et al., 2020; Scanlan et al., 2014).

The main finding was a significant association between EL variables (except DUR) and most of the IL variables (HR, TRIMP, RR and HR zones 1, 3 and 4). Our results suggest that EL and HR-based variables (IL) are correlated, agreeing with previous research that showed how internal (sRPE), and external load hold a large dose-response relationship in field-based team sports (Casamichana, Castellano, Calleja-González, Roman & Castagna, 2013; Scott, Black, Quinn & Coutts, 2013; Scott, Lockie, Knight, Clark & De Jonge, 2013) and indoor sports such as basketball (Svilar & Jukic, 2018). However, other studies indicate that this dose-response relationship is not as strong during basketball training compared with field-based team sports (Scanlan et al., 2014).

These findings conflict with the results obtained in this study, fact that could be related to the different playing level of the subjects in both studies, as higher-level competition elicits higher demands (Scanlan, Dascombe & Reaburn, 2011), and this evidence could have altered the dose-response relationship results of this study. Additionally, to minimize the parameters utilized, BST should be prioritized to monitor EL instead of DUR. Furthermore, relationship between ML and MI and IL variables could be explained due to ML and MI are derived from locomotor and inertial movements such as running, accelerations, decelerations, impacts or jumps. However, in the real practice of training. EL and IL are not mathematically distinct from one another. Thus, a problem of mathematical coupling could be presented when one parameter directly or indirectly includes the whole or part of the other and the two variables are analyzed using standard correlation.

Regarding to the relationship among EL variables, the main finding was that all EL variables present a very large to almost perfect correlation between them (range r = 0.77-0.91) except DUR (range r = 0.02-0.08). These findings also agree with previous research showing correlation between EL variables (Svilar & Jukić, 2018), in elite professional basketball, although these correlations were found during training sessions, that could elicit lower demands than game scenarios as demonstrated in women basketball studies before (Reina et al., 2019), and not during friendly competition like this study did.

Further research is needed regarding these correlations as previous studies showed higher internal demands (Cortisol levels and sRPE) during official elite basketball matches when compared to simulated matches, fact that could carry over to the exertion of external demands as this study and previous research (Svilar & Jukić, 2018), seem to point to correlation between both. Though these findings are not directly extrapolated to other conditions, these results could be beneficial for all non-elite teams that do not have the resources to monitor EL using accelerometers, being BST an optimal EL variable in these specific contexts. Another finding of this research is that the results did show a high correlation variability from small to large within IL variables (range r= 0.05-0.87). These correlations in general could help to adjust time of coaching staffs when choosing load variables to analyze, as they could obtain reliable information analyzes less variables of both EL and IL.

The findings of the present study hold valuable information that could be beneficial for basketball coaching staff, strength and conditioning coaches and sport scientists, helping them to interpret and understand the EL and IL variables and their correlation and replicate these demands during training sessions, as studies based in field sports have demonstrated that training routines do not often replicate them (Giménez, Castellano, Lipinska, Zasada & Gómez, 2020). Moreover, these findings could be beneficial for all non-elite teams that do not have the resources to collect all EL and IL variables.

Nowadays, many elite teams in professional and semi-professional basketball are unwilling to invest the usage and investment in accelerometry technology, as they are not allowed to play official games with this technology (the main leagues such as NBA, Euro league and First Spanish Division currently do not allow the use of this technology); therefore, they do not record external load data during training sessions (Fox, Scanlan, Sargent & Stanton, 2020). However, according to our results, monitoring HR-based variables could help training professionals to have a general knowledge of how the EL of their players could be, if monitored. The monitoring of HR derived variables in basketball could also be beneficial to determine individual profiles of exercise intensity, allowing professionals to determine the need to meet or exceed certain intensities during training exercises that could include manipulations in the work/rest ratio that replicates the competition and meets the intermittent nature of the sport itself. It is also a good assessment of the player´s fatigue status, which could help to determine the effect of the training program on the players and therefore the need to manipulate it if is not producing the desired outcome (Berkelmans et al., 2018). Quantifying internal load through HR monitoring in basketball can help to determine the response of the player to the stimuli that is exposed to and his/her recovery from previous sessions, poor manipulation of this factors could lead to injury or illness, and therefore, time away from the court. Nevertheless, it is important to know that EL and IL monitoring are complementary and would be beneficial to collate both methods to gain a better understanding of the session recorded. Furthermore, combining these two monitoring measures, can help to decrease injury, overtraining and improve training quality time and performance (Halson, 2014).

Finally, the study presents some limitations that should be considered when interpreting our results. Firstly, all parameters (except BST and TRIMP) are based on DUR which means that values are conditioned by the time from the beginning of the game to the end, including all stoppages in play such as free-throws, faults, out-of-bounds, break periods between quarters, time-outs, and benching time. Secondly, the HR variables were calculated using the 220 years-age formula. This suggests that the five intensity zones were generally established by percentages. Assuming that the cardiovascular response per player was the same, the age of the players is the only modulating factor. Future studies should carry out a specific maximum test to obtain the HRmax or determine it during the activity. Additionally, in future studies it would be beneficial to control variables such as score, playing positions, role player, rival's quality, tactical aspects, or other factors that directly or indirectly could influence the study results. Finally, the results are indicative of the specific team context analyzed (elite friendly games) and may not be representative of teams of different ages, competitions, playing levels and gender. In turn, further research is needed to identify if our findings hold consistent in different contexts.

In future studies it would be beneficial to control variables such as score, playing positions, role player, rival's quality, tactical aspects, or other factors that directly or indirectly could influence the study results. Furthermore, for more reliable results, additional external load parameters should be recorded and more variables (e.g., distance, high speed distance, accelerations, or decelerations) should be monitored in future investigations.

Another way to improve upcoming studies is the sample size; a large sample size could give more reliable and valid results. However, the quality of the sample always has to be a top priority, as if the study presents elite players, the results would be unique to players of that level. Likewise, the results are indicative of the specific team context analyzed (elite friendly games) and may not be representative of teams of different ages, competitions, playing levels and gender.

Conclusions

The main finding of the study indicates correlation between EL variables and most of the IL variables (HR, TRIMP, RR). Thus, an exceptionally large to almost perfect correlation within EL variables (except DUR) was encountered. Thus, BST should be prioritized to monitor EL during games instead of DUR. Monitoring HR-based variables would present general information and an estimated prediction of players EL, as well as exercise intensity, fatigue status and overall view of the players' internal load. These findings would allow basketball practitioners to prioritize their time invested in controlling their player's internal/external load as well as to select the essential variables to monitor. In addition, low budget teams would be able to control their player's internal load throughout HR-based technology and, based on the results, estimate their players external load. Controlling EL could be beneficial for practitioners as it is indicative of mechanical load, and players highly exposed to it could benefit from variations on strength programs to control the players load depending on the stage of the competitive schedule. Nevertheless, it is important to know that EL and IL monitoring are complementary to each other, both allow basketball training professionals to obtain better understanding of the sessions performed and therefore lead them to a better programing of the next training sessions and games.

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