ANALYSIS OF WEEKLY INTERNAL AND EXTERNAL LOAD FLUCTUATION IN PROFESSIONAL BASKETBALL

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Original scientific paper
DOI 10.26582/k.56.2.8

Abstract:

The present work analyzes the weekly load fluctuation, internal and external, throughout a season in a professional basketball team. To analyze the internal load factor, the session Rate of Perceived Exertion (sRPE) has been used, and the Integral Analysis System of Training Tasks (SIATE) has been used to monitor the external load. This is the first work that analyzes the complementary use of these two low-cost load monitoring tools. Firstly, the scores distribution obtained in both tests has been characterized. Secondly, an important and positive correlation was found since the association between the scores in sRPE and SIATE shows to increase together. Finally, we compared the scores of the study groups corresponding to the weeks without match (0-g), with one match (1-g) and with two matches (2-g) in each of the variables. Regarding sRPE, differences have been found between 0-g and 2-g, and between 1-g and 2-g. Furthermore, we observed differences in SIATE between 0-g and 1-g, 1-g and 2-g, and between 0-g and 2-g. Taken altogether, our study suggests that the complementary use of sRPE and SIATE is an effective and methodical monitoring training system.

Key words: *session Rate of Perceived Exertion; Integral Analysis System of Training Tasks; internal load; external load; weekly load fluctuation.*

Introduction

Basketball is a team sport marked by intermittent high intensity and short-lasting efforts, which alternate with periods of low to moderate activity (Stojanović, Stojiljković, Scanlan, Dalbo, Berkelmans, & Milanović, 2018). The key biomechanical movements in basketball performance include sprints, accelerations, jumps, decelerations, lateral movements and changes of direction (Paulauskas, Kreivyte, Scanlan, Moreira, Siupsinskas, & Conte, 2019; Scanlan, Went, Tucker, & Dalbo, 2014). The average distance traveled during elite matches varies depending on the references consulted, covering ranges from 1.9 km to 6.3 km (Schelling & Torres-Ronda, 2013). The average intensity is above the lactate threshold, that is 5.1 ± 1.3 mmol/l with heart rate reaching 85% of the maximum possible, between 150 and 170 beats per minute (bpm) (Edwards, Spiteri, Piggott, Bonhotal, Haff, & Joyce, 2018).

The basketball season along with other sports such as football, rugby or volleyball, is one of the longest competitions in sports. A team competing in the NBA plays an average of 82 regular league games (Taylor, Chapman, Cronin, Newton, & Gill, 2012), while a Euroleague team can play up to 70 games, considering double competition between Europe and the National League (Svilar, Castellano, & Juckic, 2018).

In order to adjust training loads, it is necessary to know competitive demands and basketball games density that a team faces. Thus, a detailed understanding of the game calendar and scheduling training loads according to the weekly needs (one, two or even three games a week) will be essential to control both acute and chronic workloads (Gabbett, 2020; Manzi, D'ottavio, Impellizzeri, Chaouachi, Chamari, & Castagna, 2010).

The session Rate of Perceived Exertion (sRPE) is a reliable and valid tool, affordable and very easy to implement to monitor training loads in team sports (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Lambert & Borresen, 2010). Piedra, Peña, & Caparrós (2021) reported weekly average internal load values (sRPE) between 2250 and 5058 arbitrary units (AU). Manzi, et al. (2010) characterized this load based on the number of weekly matches: 3334±256 AU for weeks without competition, 2928±303 AU for weeks with one match, and 2928±303 AU for weeks with two or more matches.

In professional sport, controlling training load is relevant to optimize performance (Akenhad & Nassis, 2015; Drew & Finch, 2016; Gabbett, 2004; Hulin, Gabbett, Caputi, Lawson, & Sampson, 2016) and reduce injury risks, especially to those to soft tissues and/or without contact (Soligard, et al., 2016). In elite teams, the number of injuries is around 23 incidents per season (Piedra, et al., 2021). Thus, an improved load control may help to obtain a better understanding of the athletes' responses to training, their recovery needs, and their fatigue status. The highest levels of fatigue and injuries are associated with high peak loads in highly competitive density calendars (Edwards, et al., 2018), for which it is estimated that basketball players need between 24-48 hours of post-match recovery before the next high intensity training session.

The same dose of training (external load) will generate different physiological responses (internal load) in the athletes' bodies (Lambert & Borresen, 2010), depending on their playing profile, playing position, age, injury history, and level of physical condition. For this reason, appropriate monitoring in the prescription of individualized external loads is necessary (Fox, Scanlan, & Stanton, 2017). Importantly, it is worth considering that the training methodology has been shown to explain between 24-100% of the variation in internal-external load relationships (McLaren, Macpherson, Coutts, Hurst, Spears, & Weston, 2017).

A statistically significant correlation has been found between the data collected using the comprehensive task analysis system in training known as SIATE (Ibáñez, Feu, & Cañadas, 2016), the Player Load variable (PL) collected by inertial devices, and the percentage of maximum heart rate (%MHR). Reina, Mancha-Triguero, García-Santos, García-Rubio, & Ibáñez (2019) confirmed the direct relationship of low-cost SIATE with inertial monitoring systems (for external load control) and heart rate devices (for internal load). Furthermore, the strong correlation found by Svilar, et al. (2018) between internal load (sRPE) and external load (PL) in professional basketball players justifies the use of sRPE as a load control indicator in intermittent impact sports.

Based on the above, the objective of this study was to analyze the fluctuation of both internal and external weekly loads throughout a season in a professional basketball team. Specifically, the aim was to: 1) characterize the distributions of the scores obtained in the sRPE and SIATE; 2) study the association between the scores achieved in the sRPE and SIATE; 3) make a comparison between the scores of the groups corresponding to the weeks without a match (0-g), with one match (1-g) and with two matches (2-g) in each of the variables of sRPE and SIATE.

Methods

In the current research, the retrospective descriptive study, records of 280 training sessions practiced between August 2020 and May 2021 were used. The 2020/2021 season was seriously impacted by the global pandemic of COVID-19, which caused multiple matches to be postponed and several changes in work planning to be made. All mesocycles presented had the same structure (Table 1), composed of 5 microcycles, which could be microcycles without a match (0-g) (n=8), regular microcycles with a single match (1-g) (n=17), or congested microcycles with two or more matches (2-g) (n=15).

Participants

Participants in this research were members of a professional team (Bilbao Basket) that played two competitions during the period analyzed: the main professional basketball league in Spain (Liga Endesa) and the Basketball Champions League (European competition). Throughout the season analyzed, up to 20 professional basketball players made up the team's roster, but only seven of them were part of the final sample. Like in Clemente, Mendes, Bredt, Praça, Silvério, Carriço & Duarte (2019), the inclusion criteria necessary to be part of the final analysis were: a) completing 80% of the total mesocycles; b) carrying out 80% of the sessions of the corresponding mesocycle; and c) passing the medical examination that accredits athletes to be able to exercise at a professional level.

The study was conducted in accordance with the Declaration of Helsinki and included the club's authorization, participants' informed consent and a favorable report from the ethics committee of the University of La Rioja (file no. 76529).

Procedure

The sRPE was used to analyze the internal load factor. The questionnaire on perceived exertion (RPE) was quantified from 1 to 10 in two categories: a) muscular level: 1= rest, 5= challenging, 10= maximum; b) cardiovascular level: 1 = easy, 5 = intense, 10 = breathless. This categorization provides more precise information on the characteristics of the effort and the potential risk of injury mechanisms (Jones, Griffiths, & Mellalieu, 2017; Los Arcos, 2014). The final result is obtained from the average of the muscular and cardiovascular variables. This questionnaire was completed individually 15-45 minutes after finishing the training

Table 1. Timeline of the study shows sessions from the 2021/2022 season

Mesocycle 1	Week 1	Week 2	Week 3	Week 4	Week 5	Total
No. of games	0	1	2	1	2	6
No. of team practices	10	9	9	7	5	40
Total	10	10	11	8	7	46
Mesocycle 2	Week 6	Week 7	Week 8	Week 9	Week 10	Total
No. of games	1	2	1	1	0	5
No. of team practices	7	6	7	6	7	33
Total	8	8	8	7	7	38
Mesocycle 3	Week 11	Week 12	Week 13	Week 14	Week 15	Total
No. of games	0	2	2	2	1	7
No. of team practices	7	7	6	6	2	28
Total	7	9	8	8	3	35
Mesocycle 4	Week 16	Week 17	Week 18	Week 19	Week 20	Total
No. of games	0	2	2	1	2	7
No. of team practices	8	6	5	7	2	28
Total	8	8	7	8	4	35
Mesocycle 5	Week 21	Week 22	Week 23	Week 24	Week 25	Total
No. of games	2	1	2	1	2	8
No. of team practices	4	6	5	5	5	25
Total	6	7	7	6	7	33
Mesocycle 6	Week 26	Week 27	Week 28	Week 29	Week 30	Total
No. of games	1	0	0	1	1	3
No. of team practices	5	5	5	5	6	26
Total	6	5	5	6	7	29
Mesocycle 7	Week 31	Week 32	Week 33	Week 34	Week 35	Total
No. of games	1	1	1	1	0	4
No. of team practices	4	5	6	5	5	25
Total	5	6	7	6	5	29
Mesocycle 8	Week 36	Week 37	Week 38	Week 39	Week 40	Total
No. of games	1	2	0	2	3	8
No. of team practices	6	6	4	5	5	27
Total	7	8	5	7	8	35

session (Clemente, Mendes, Nikolaidis, Calvete, Carriço, & Owen, 2017; Singh, Foster, Tod, & McGuigan, 2007), using the Teambuildr Training software (TeamBuildr, Silver Spring, MD, USA), where each player had their own user account. Once the player's RPE assessment was completed, the sRPE (or RPE of the session) was calculated, relating the resulting value of the player's average RPE (subjective nature) multiplied by the useful minutes of practice (objective nature). To obtain the sRPE, the initial and final part of the session were not included at the time of the calculation. The results obtained were expressed in arbitrary units (AU) (Reina, et al., 2019; Scanlan, et al., 2014).

To monitor the external load, the integral analysis system of training task (stands for SIATE in Spanish) was used. This is a monitoring system characterized by being universal, standardizable, modular and flexible (Ibáñez, et al., 2016). This tool controls six variables: degree of opposition, task density, number of simultaneous performers, competitive load, game space, and cognitive involvement. These variables are classified from 1 to 5 (5 being assigned as the highest load), which allows strength and conditioning coaches to easily evaluate the load quantitatively. From the aforementioned variables, other secondary variables emerge, such as the task load, explained as the sum of the value assigned to each of the six primary parameters (from 1 to 5 points) which ranges from 6 to 30 AU, and the load of the task for useful practice time. This parameter has been shown to more accurately reflect the actual load of the task (Fuster, Caparrós, & Capdevila, 2021; Reina, et al., 2019). Furthermore, this tool enables an objective control of the external load in training for contexts where economic and technological resources are limited. As with the internal load control, the time of the initial and final part of the session was not used for the calculation of the total SIATE of the session.

Data analysis

The data analysis was divided into two sections. The objective of the first section was to analyze the relationship between the sRPE and SIATE variables. To this end, the statistical significance of the association between the tests was determined by calculating the Pearson correlation coefficient, since the variables were considered quantitative, showing a linear relationship, and following a normal distribution. Interpretation of the data was performed following the criteria established by Cohen (1988, as cited in Hopkins, Marshall, Batterham, & Hanin, 2009). According to the aforementioned criteria, values close to 0.10 indicate a small relationship, those near 0.30 indicate a medium relationship, and those around 0.50 suggest a large relationship. In addition, this analysis was completed with the representation of the variability of the standardized Z scores in order to determine the joint distance of the values obtained in the variables under analysis.

Next, in the second block, the purpose of the analysis focused on evaluating whether the mean values in the sRPE and SIATE variables showed statistically significant differences depending on the number of matches played each week. Thus, a global analysis of variance for independent samples was carried out in which the Brown-Forsythe contrast statistics was calculated (Brown & Forsythe, 1974), given that non-compliance with the assumption of homogeneity of variances between groups using Levene's test. To evaluate the magnitude of the effect, the eta squared statistics (η^2) was calculated. Once the statistical significance of the differences between the group averages in both variables was verified, the t-test for means' contrast was applied, with the Bonferroni correction, to know at what levels these differences occur. The effect size of the contrasts carried out was analyzed using Cohen's d statistics, where values around 0.20 indicate a small effect size, those close to 0.50 are considered medium, and equal to or greater than 0.80 are interpreted as large (Cohen, 1988, as cited in Hopkins, Marshall, Batterham & Hanin, 2009). The statistical analysis of the data were carried out using the IBM-SPSS-27 program.

Results

Descriptive statistics of the variables

Figure 1 presents descriptive data illustrating fluctuations of direct scores across weeks for both sRPE and SIATE variables. In relation to the sRPE variable, the average value was 2140.92 ± 791.99 AU. The coefficient of variation was 0.37, the highest weekly load was 4152 AU in week 28, while the lowest was 256 AU in week 15. Regarding the SIATE variable, the average has been located at 6679.76 ± 1893.61 AU. The coefficient of variation was 0.28. In this case, the highest weekly load was 4152 AU in week 11, and the lowest was 2019 AU in week 15. Finally, the comparison of the coefficients of variation revealed greater variability in the scores of the sRPE variable.

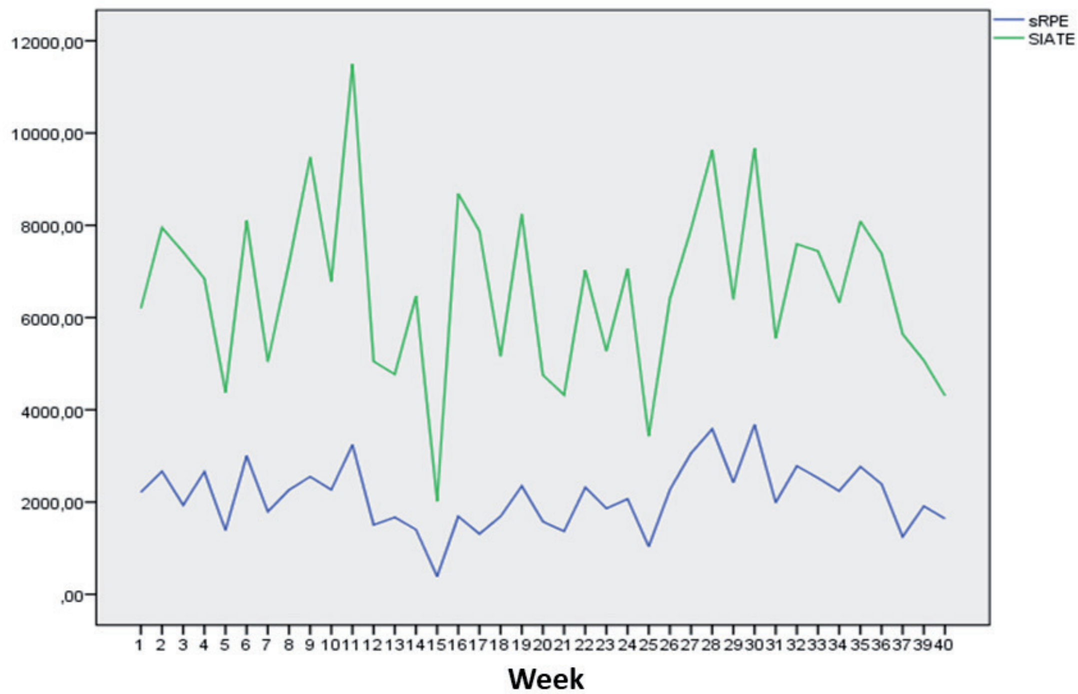

Figure 1. Fluctuation of the sRPE and SIATE variables between weeks throughout the season expressed in direct scores.

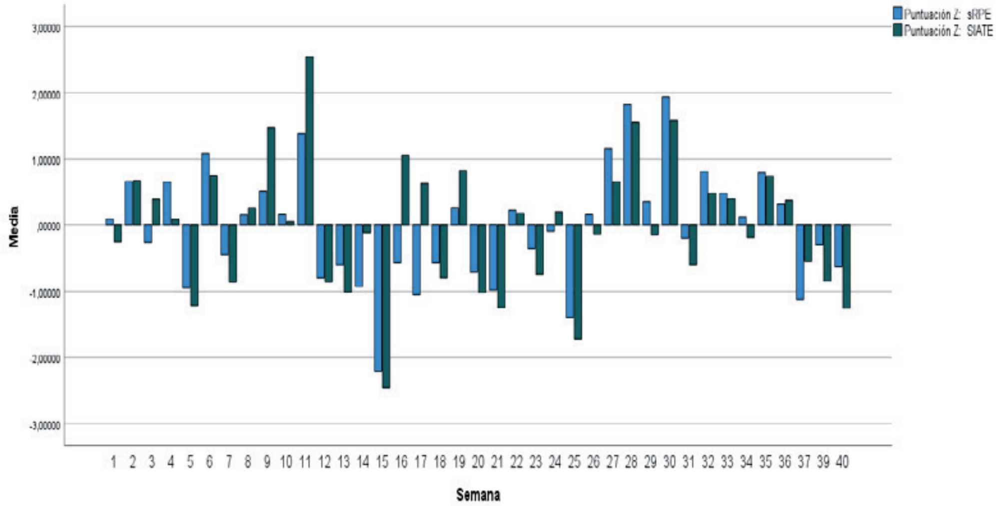

Figure 2. Fluctuation of the variability of the standardized Z scores of the sRPE and SIATE variables between weeks throughout the season.

Table 2. Group contrasts

	sRPE				SIATE			
	Mean ± SD	0-g vs. 1-g	0-g vs. 2-g	1-g vs. 2-g	Mean ± SD	0-g vs. 1-g	0-g vs. 2-g	1-g vs. 2-g
0-g	2364.11±954.41	p=.188 d=0.306	p<.001 d=1.612	p<.001 d=1.306	7984.88±1909.70	p=.002 d=0.568	p<.001 d=1.661	p<.001 d=1.093
1-g	2390.98±743.30				7079.34±1680.73			
2-g	1532.90±446.89				5336.15±1216.26			

Note. d = Cohen's d; 0-g = no game per week; 1-g = one game per week; 2-g = two games per week.
* Significant differences (n.s. 0.01)

Association between the variables

On the other hand, the Pearson correlation between the scores obtained in sRPE and SIATE were both statistically significant ($r = 0.721$; $p<.01$), indicating a large and direct relationship. In this regard, the weeks with higher values in the sRPE variable corresponded to weeks with higher levels in the SIATE variable, as shown in Figure 2. One of the reasons was that the trend of this relationship was altered along eight weeks, where the association was reversed. Specifically, in weeks 1, 26 and 29, while the players assigned positive values to the sRPE variable, these corresponded to low values in the SIATE variable. In contrast, during weeks 3, 16, 17, 24 and 34, the association was found of opposite nature: high values in the sRPE variable were associated with low values in the SIATE variable.

Contrast between the groups

The analysis of variance test for the global contrast of independent samples was found to be statistically significant for both the sRPE ($p<.001$; $\eta^2 = 0.297$) and SIATE ($p<.001$; $\eta^2 = 0.317$) variables between the corresponding groups of 0-g, 1-g, and 2-g.

In the pairwise comparison, as detailed in Table 2, the mean contrast test for independent groups determined the existence of statistically significant differences between the groups: 0-g and 2-g ($p=.018$; $d = 1.612$) and 1-g and 2-g ($p<.001$; $d = 1.306$) in the sRPE variable. In relation to the SIATE variable, statistically significant differences were present between 0-g and 1-g ($p=.002$; $d = 0.568$), 0-g and 2-g ($p<.001$; $d = 1.661$), and 1-g and 2-g ($p<.001$; $d = 1.093$). Likewise, the size effect of the differences that were statistically significant occurred when comparing between 0-g and 1-g in the SIATE variable and high in the rest of the contrasts.

Discussion and conclusions

The objective of this research was to analyze the fluctuations of both internal and external weekly loads using sRPE and the integral analysis system of training tasks (SIATE), respectively, in a professional basketball team throughout a season (Ibáñez, et al., 2016). To the best of authors' knowledge, this is the first research that analyzes the complementary use of these two low-cost load monitoring tools in men's professional basketball.

We first characterized the distribution of the scores obtained in the sRPE and SIATE, revealing a notable fluctuation in the load, especially in relation to the sRPE, throughout the season, in line with the results obtained by Manzi, et al. (2010) and Salazar, García, Svilar, & Castellano (2021). The highest average sRPE values corresponded to 1-g and the lowest to 2-g; while for SIATE the highest mean values occurred in 0-g and the lowest mean values were assigned to 2-g. Consistent with Svilar, et al. (2018) and Paulauskas, et al. (2019), we found that high competitive density (two games per week) reduces the time available to schedule training sessions sufficiently far from the competition to ensure players' recovery, which was reflected in the decrease in the training load in both the sRPE and SIATE. During weeks without competition the training load was higher due to a greater gap between matches and the need to maintain the competitive pace.

Secondly, the association between the sRPE and SIATE scores achieved has been studied. The positive and large correlation between internal and external load detected in the present study corresponds to previous research that has explored this connection among other sports (Reina, et al., 2019). Positive and important correlation has been found between the sRPE and SIATE scores ($r = 0.721$) since the values of both variables tend to increase together. Previous studies examined the relationship between external load, evaluated through variables such as Player Load, and the subjective perception of effort in different sports (Kniubaite, Skarbalius, Clemente, & Conte, 2019; Svilar, et al., 2018). Furthermore, positive correlations have been found between external load and physiological parameters, such as heart rate, which helped to understand the adaptive physical response to training (Reina, et al., 2019; Scanlan, et al., 2014). In line with these studies, our measurement tools have proven to be sensitive to load fluctuation over the course of a season and displayed to be strong.

Finally, a comparison was made between the scores of the groups corresponding to the weeks without game, to those with one game, and those with two games in each of the sRPE and SIATE variables. In relation to sRPE, differences were found between 0-g and 2-g and between 1-g and 2-g, supporting the impact that competitive density has on the weekly load (Piedra, et al., 2021). The values of internal (sRPE) and external (SIATE) load during weeks without competition and weeks with one game were higher than those obtained during weeks of higher competitive density (two or more games), coinciding with the results of researchers who showed the same trend for internal load (Manzi, et al., 2010) and external load (Salazar, et al., 2020).

The comparative analysis for the SIATE showed significant differences between 0-g and 1-g; 1-g and 2-g; and between 0-g and 2-g. Interestingly, these contrasts between 0-g, 1-g, and 2-g have not been carried out for SIATE till now (Ibáñez, et al., 2016). Our findings support the use of this load monitoring tool, which has proven to be: universal – because it is implemented in a basic Office application, spreadsheet type; standardizable – thanks to the classification of each of the categories of its basic variables, which allows comparing data from different teams and sports levels; modular – since the amount of information that coaches can record in each training task can be defined; and flexible – as it presents various variables with multiple classification categories.

Finally, our results agree with those obtained in previous investigations (Aoki, et al., 2016; McLaren, et al., 2018; Scanlan, et al., 2014) that used other load monitoring tools such as sRPE, TRIMP and accelerometers, confirming significant differences found between the variables based on the number of matches per week (Manzi, et al., 2010). Our findings indicate that both the external load (SIATE) and the player's perception of effort (sRPE) are sensitive to differentiate between weeks with different numbers of matches. The relationship between external and internal load depending on the different competitive density is a key aspect in considering training programming to optimize performance and well-being of players (Conte, Kolb, Scanlan, & Santolamazza, 2018). The results of this article corroborate the complex nature of load management in professional basketball (Salazar, et al., 2020; Svilar, et al., 2018).

In this article and for the first time with elite basketball players, the appropriateness has been demonstrated of using these two ecological tools that allow controlling both internal load (sRPE) and external load (SIATE) in a complementary way, thus making them an effective and methodical monitoring system. The use of both low-cost tools can help coaches and physical trainers to optimize sports performance and reduce the risk of injury not only in professional contexts but also in amateur teams with limited resources.

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Submitted: February 12, 2024
Accepted: April 28, 2024
Published Online First: December 11, 2024

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