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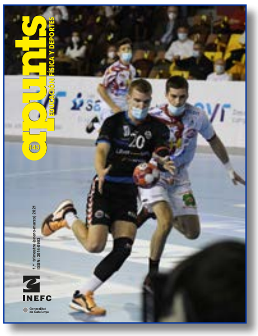

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Heart Rate Variability and Accelerometry: Workload Control Management in Men's Basketball

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Handball Spain: Ademar León and Liberbank Sinfín play the first match with masks during a Sacyr Asobal league game in October 2020, to comply with the regional regulations of COVID-19. J.Casares/(EPA) EFE/ lafototeca.com

Abstract

With a view to ascertaining the existence of possible relationships between internal load and external load in basketball, a prospective, observational and descriptive study was performed spanning 20 training sessions during the competitive season of a men's amateur basketball team. Heart rate variability was recorded over 10 sessions using Fitlab® software, and it was subsequently recorded in a further 10 sessions by means of accelerometry with Polar Pro Team® software. The exercises performed and their specificity were analysed; the RRmean, SDNN, RMSSD, pNN50, SHRZ, %SHRZ internal load variables; and the external load variables, namely level 1 accelerations, 0.5 to 0.99 m/s^2; level 2 accelerations, 1 to 1.99 m/s^2; level 3 accelerations, 2 to 2.99 m/s^2; level 4 accelerations, 3 to 50 m/s^2; level 1 decelerations, –0.5 to –0.99 m/s^2; level 2 decelerations, –1 to –1.99 m/s^2; level 3 decelerations, –2 to –2.99 m/s^2 and level 4 decelerations, –3 to –50 m/s^2. A correlation analysis showed significance between external and internal load (SDNN and Total Ac-Dec; rho = .78, p = .004) and specificity (SHRZ and exercise; rho = .89, p = .012). Multiple linear regression analysis showed that internal load (RRmean) depends on external load (total accelerations and decelerations; R^2 = .84). A linear regression indicated that internal load (%SHRZ) also depends on the specificity of the training (R^2 = .59). The results suggest significant relationships between internal load, external load and exercise specificity during training.

Keywords: internal load, external load, HRV, %SHRZ, RRMean, accelerations, decelerations.

Introduction

Internal load (IL) has proven to be useful in guiding the training process in basketball (Sansonea et al., 2019), controlling fatigue (Pyne & Martin, 2011) and preventing injuries (Ivarsson et al., 2013) in a sport involving major physiological and psychological stress (Moreira et al., 2012). One parameter for measuring IL is heart rate variability (HRV), regarded as an effective tool in monitoring adaptation to daily load and to the training programme (Capdevila et al., 2008). The RR record (electrocardiographic interval between two successive R waves) can be used to obtain time parameters that define HRV: mean of the RR intervals (RRmean), standard deviation of the RR intervals (SDNN), root mean square of the successive differences of RR intervals (RMSSD), and percentage difference of the normal adjacent RR intervals >50m/s (pNN50) (Moreno et al., 2013). These time parameters are associated with predominance of the parasympathetic system and as a global indicator, among others, of a sportsperson's psycho-physiological fatigue (Schmitt et al., 2015). Another parameter related to heart rate (HR) in basketball is SHRZ (Summated-Heart-Rate-Zones) (Edwards, 1993; Soligard et al., 2016). This is based on the time spent in predefined HR intensity areas according to five discrete areas of HR in relation to HR_{max} (maximum heart rate). A multiplier accompanies each HR zone that attributes greater weight to higher relative HR responses that are typical of acyclic sports such as basketball (Scanlan et al., 2014).

External and internal loads (EL and IL, respectively) are related, the former being defined as an external physical stimulus applied to the sportsperson during training (or competition) (Soligard et al., 2016). Accelerometry is a tool which can be used to quantify EL (Boyd et al., 2011). Coaches can employ these devices to adjust loads (Foster, et al., 2017) in order to reduce the risk of players sustaining injuries during the season (Caparrós et al., 2018).

Both IL and EL are parameters used to independently assess the effect of training on a player and their control is integrated into training in amateurs and professionals alike (Foster et al., 2017). A certain EL will induce different individual physiological and psychological responses in the same team; this response is the IL (Soligard et al., 2016). Assessing the relationships between both loads on an individual basis provides specific information about each player as a specific tool in order to control adaptation (Impellizzeri et al., 2019) and recovery (Guillaumes et al., 2018) processes.

Analysing these variables in the course of training sessions during the season will enable the coaching staff to design exercises to better adapt workloads to the required objectives. As for its applicability to basketball, Schelling and Torres (2013) propose a classification to facilitate load programming and control without the direct use of technologies because the specificity of the exercises is divided according to levels of approach. The exercises may be general (levels 0^-, 0^+, I), directed (levels II, III), special (level IV) and competitive (level V) depending on the orientation of the task and player needs. Relating this to exercises, 1v0, 2v0 and 3v0 (exercises including up to 3 players without opposition) would correspond to level III. The special level IV would comprise 2v2, 2vX, 3v3, 3vX, and 4vX (small-sided game in equal, inferior or superior conditions); and level V would correspond to 4v4, 5vX and 5v5 (8 players upwards, small-sided game, superiority or real play).

The objective of this study was to assess the possible relationships between IL (based on HRV) and EL (based on accelerometry) in the different levels of approach to training exercises in amateur basketball.

Methodology

Participants

Twelve players took part in the study (age: 26.5 ± 8.8; height: 190 ± 7 cm; weight: 92 ± 6.2 kg) from a men's basketball team in the Copa Catalunya division in the competitive period of the 2018-2019 season. The entire team and its echelons (players, coaches and management) were informed about the study and provided their consent for it to be performed. Data use fulfilled the standards of the Helsinki Declaration, revised at Fortaleza (World Medical Association, 2013).

Variables recording

Each player was given a chest strap (Polar Team Pro Sensor) to record the RR intervals (time between consecutive heartbeats in milliseconds) and the accelerometry. These devices contain a pulsometer and an MEMS 200 Hz motion sensor (accelerometer, gyroscope, digital compass) and built-in 10 Hz GPS. A sensor was assigned to each player (Polar Pro Team Sensor®) which relayed the data collected during the training sessions by the team's physical fitness coach via Bluetooth to a mobile device (iPad). The RR intervals were stored in the app and were analysed with Fitlab® software (www.HealthSportLab.com; Barcelona, Spain) specifically created to perform HRV studies (Guillaumes et al., 2018). The software filtered out possible recording errors and made it possible to monitor all the players' IL parameters simultaneously in real time. The accelerometer (Boyd et al., 2011) was stored in the app and was analysed with Polar Team Pro® software (https://teampro.polar.com; Kempele, Finland).

Variables studied

The IL variables analysed were: RRmean, SDNN, RMSSD, pNN50, the summated-heart-rate-zones (SHRZ) model and the % summated-heart-rate-zones (%SHRZ) model. The EL variables analysed were: accelerations and decelerations, divided into level 1 accelerations (A-1, between 0.50 m/s^2 and 0.99 m/ s^2), level 2 accelerations (A-2, from 1.00 m/s^2 to 1.99 m/s^2), level 3 accelerations (A-3, 2.00 m/s^2 to 2.99 m/s^2), level 4 accelerations (A-4, 3.00 m/s^2 to 50.00 m/s^2); level 1 decelerations (D-1, –0.50 m/s^2 to –0.99 m/s^2), level 2 decelerations (D-2, from –1.00 m/s^2 to –1.99 m s^2), level 3 decelerations (D-3, –2.00 m/s^2 to –2.99 m/s^2), level 4 decelerations (D-4, –3.00 m/s^2 to –50.00 m/s^2), total accelerations (Total_Ac, sum of A-1, A-2, A-3, A-4), and total decelerations (Total_Dec, sum of D-1, D-2, D-3, D-4). Total A-D is the total sum of accelerations and decelerations.

Adapting the classification by Schelling and Torres (2013), the specificity of the exercises was provided for according to levels of approach: level III, IV and V. Provision was also made for half-court (1/2) and full-court (1/1) exercises.

Procedure

A total of 20 training sessions (two weekly sessions for 10 consecutive weeks) were recorded. The recording was divided into two phases: a) continuous recording of HRV for the IL analysis in the course of 10 sessions, both the entire session and on a by-exercise basis, excluding records with artefacts >15%; b) recording of the accelerometry values for the EL analysis for the subsequent 10 sessions, both the entire session and on a by-exercise basis.

The sensor assigned to the players was fitted before each session following the instructions of the physical fitness coach. The data were recorded individually in simultaneous and synchronised fashion. The team trained three days a week, and the first and second weekly training sessions, which lasted between 75 and 90 minutes, were recorded, beginning with one level III exercise, followed by one or two level IV exercises and with the best part of the training session focusing on level V exercises.

Statistical analysis

The analysis was performed with JASP statistical software, version 9.2.0 (Jasp Team, Amsterdam). A central tendency analysis of the IL, EL and levels of specificity of the training exercises was performed. Taking the non-normality of the sample into account, and with the objective of determining the independence of the variables, the Kruskal-Wallis test was applied to the set of variables pertaining to the training sessions and exercises grouped according to their specificity. The Friedman test was used to evaluate the independence of the variables analysed in the course of the sessions. Subsequently, using the average values of the exercises for which IL and EL variables were available and taking sample size (<30) into account, Spearman's Rho coefficient was applied to ascertain possible correlations. Finally, taking the normality of these values into account, their possible relationship of dependence was ascertained by means of simple and multiple linear regression analyses. The level of significance for all the analyses is $p<0.05$. The exact level of significance for each coefficient of correlation is indicated and the values are expressed as the mean ± standard deviation.

Results

In the course of the 10 sessions in the first phase, 145 valid records were obtained for IL from a total of 177. Taking into account their specificity according to the type of exercise for level III, 30 ½ shot records were made in three different sessions; for level IV, four 2x2 ½ records in one session and 33 3x3 Attack-Def-Rest records in three different sessions; for level V, 11 4x4 1/1 records for one session and 67 5x5 1/1 records in five sessions. In the IL descriptive analysis, SHRZ presented the highest average value in 5x5 1/1 (72.10 ± 39.56) and the lowest in ½ shot (12.45 ± 6.09). Similarly, %SHRZ presented the highest average value in 5x5 1/1 (73.17 ± 16.44) and the lowest in ½ shot (48.57 ± 17.86). RRmean behaved in the opposite fashion, with the highest average value in ½ shot (488.07 ± 61.18) and the lowest in 5x5 1/1 (414.84 ± 46.38). SDNN had the highest average value in 2x2 ½ (45.01 ± 13.52) and the lowest in ½ shot (35.46 ± 17.86) (Table 1).

In the course of the 10 second-phase sessions, a total of 171 valid records were obtained for EL. For level III, 23 ½ shot records in one session and 1/1 shot, 10 records in three different sessions; for level IV, 1x1 ½, 18 records in two sessions, 10 2x2 ½ records in one session, 10 3x3 Attack-Def-Rest records in one session and 3x3 ½, 11 records in one session; for level V, 45 4x4 1/1 records over four sessions and 44 5x5 1/1 records in another four. EL presented the highest total Ac-Dec values in 4x4 1/1 (335.31 ± 166.16) and 5x5 1/1 (427.36 ± 235.04) exercises and the lowest values in ½ shot (142.75 ± 31.27) and in 1x1 1/1 (101.20 ± 29.33).

The exercises were distributed in five groups according to their specificity: ½ shot, 2x2 ½, 3x3 1/1 (in its Attack-Defence-Rest variant), 4x4 1/1 and 5x5 1/1. The IL and EL variables behaved independently. There were significant differences between the different exercises analysed according to specificity for the SHRZ ($W = 146.50$; $p = <.001$) and RRmean ($W = 88.45$; $p = <.001$) parameters of IL and for the Total Ac-Dec EL parameter ($W = 94.77$; $p = <.001$). Significant differences were observed between the set of IL

Table 1
Internal variables (mean and SD) recorded in the training sessions according to level of approach (based on Schelling & Torres, 2013) and exercise for 12 amateur basketball players (n=145).

Levels of approach	Number of records	RRmean	SDNN	RMSSD	pNN50	SHRZ	%SHRZ
	n	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Level 3 Directed							
½ shot	30	488.07 ± 61.18	35.46 ± 17.86	7.69 ± 5.27	.47 ± 1.75	12.45 ± 6.09	48.57 ± 17.86
Level 4 Special							
2x2 1/2	4	487.74 ± 65.13	45.01 ± 13.52	8.29 ± 3.81	.16 ± .27	13.83 ± 4.36	49.33 ± 15.31
3x3 1/1 At Def Rest	33	422.88 ± 38.30	37.94 ± 15.91	6.69 ± 2.55	.20 ± .29	14.36 ± 8.02	69.78 ± 14.32
Level 5 Competitive							
4x4 1/1	11	422.99 ± 45.90	42.85 ± 10.04	6.32 ± 2.59	.12 ± .13	53.95 ± 13.20	70.13 ± 14.05
5x5 1/1	67	414.84 ± 46.38	43.49 ± 19.16	7.94 ± 5.79	.33 ± .54	72.10 ± 39.56	73.17 ± 16.44

values of the exercises grouped according to their specificity ($F=28.18$; $p<.001$) and sessions ($F=10.44$; $p<.001$) and of EL values between the exercises grouped according to their specificity ($F=50.74$; $p<.001$) and sessions ($F=24.52$; $p<.001$).

As for the relationships between IL and EL values corresponding to the exercises depending on their specificity, significant correlations were observed between SDNN and Total Ac-Dec (rho = .786; $p=.0048$) as well as between SHRZ and specificity (rho = .893; $p=.012$).

Table 2
Accelerations and decelerations (mean and SD) recorded in the training sessions according to level of approach (based on Schelling & Torres, 2013), intensity and exercise for 12 amateur basketball players (n=171).

Levels of approach	Number of records	A-1	A-2	A-3	A-4	D-1	D-2
	n	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Level 3 Directed							
½ shot	23	28.13 ± 4.39	41.25 ± 7.42	4.0 ± 1.93	.00 ± .00	24.75 ± 4.92	34.00 ± 6.82
1/1 shot	10	51.32 ± 36.04	66.95 ± 50.33	13.95 ± 14.87	.09 ± .29	52.59 ± 37.22	65.77 ± 49.84
Level 4 Special							
1x1 1/1	18	17.10 ± 5.40	26.10 ± 5.04	7.60 ± 3.75	.00 ± .00	17.10 ± 4.65	24.70 ± 5.76
2x2 1/2	10	41.60 ± 8.90	57.60 ± 7.09	14.20 ± 5.53	.00 ± .00	44.0 ± 7.07	53.90 ± 7.29
3x3 1/1	11	32.0 ± 6.03	50.73 ± 10.76	16.82 ± 7.47	.00 ± .00	31.45 ± 9.08	53.00 ± 9.26
3x3 1/1 At Def Rest	10	31.0 ± 7.32	45.90 ± 9.59	15.90 ± 5.55	.00 ± .00	35.30 ± 7.30	47.20 ± 6.27
Level 5 Competitive							
4x4 1/1	45	59.84 ± 30.23	84.78 ± 40.37	20.79 ± 12.19	.05 ± .22	61.02 ± 28.47	83.40 ± 38.79
5x5 1/1	44	75.97 ± 41.14	105.99 ± 54.39	28.91 ± 20.19	.23 ± .84	78.84 ± 45.22	103.48 ± 50.53

Table 2 *(continued)*
Accelerations and decelerations (mean and SD) recorded in the training sessions according to level of approach (based on Schelling & Torres, 2013), intensity and exercise for 12 amateur basketball players.

Levels of approach	No. of records	D-3	D-4	Total Ac	Total Dec	Total Ac-Dec
	n	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Level 3 Directed						
½ shot	23	9.88 ± 5.08	.75 ± .71	73.38 ± 13.14	69.38 ± 17.54	142.75 ± 31.27
1/1 shot	10	15.27 ± 12.98	2.68 ± 3.90	132.32 ± 101.54	136.32 ± 103.94	268.64 ± 205.48
Level 4 Special						
1x1 1/1	18	5.70 ± 2.54	2.90 ± 2.18	50.80 ± 14.20	50.40 ± 15.13	101.20 ± 29.33
2x2 1/2	10	14.70 ± 4.42	2.70 ± 2.50	113.40 ± 21.52	115.30 ± 21.29	228.70 ± 42.81
3x3 1/1	11	14.45 ± 6.68	4.91 ± 2.12	99.55 ± 24.26	103.82 ± 27.15	203.36 ± 51.41
3x3 1/1 At Def Rest	10	13.10 ± 2.96	4.30 ± 3.47	92.80 ± 22.45	99.90 ± 20.00	192.70 ± 42.45
Level 5 Competitive						
4x4 1/1	45	21.40 ± 11.53	4.04 ± 4.36	165.45 ± 83.01	169.86 ± 83.15	335.31 ± 166.16
5x5 1/1	44	28.25 ± 17.86	5.71 ± 4.98	211.09 ± 116.56	216.28 ± 118.49	427.36 ± 235.04

Table 3
Results of the multiple linear regression analysis that accounts for RRMean (IL) according to total accelerations and decelerations (EL).

Regression model summary

Model	R	R^2	Adjusted R^2	RMSE
1	.92	.84	.77	30.30

Predictive variables: Tot_AC, Tot_DEC
Dependent variable: RRmean

ANOVA of the equation

Model	Sum of squares	df	Mean squares	F	p
1 Regression	20356	2	10177.8	11.09	.02
Residual	3671	4	917.8		
Total	24027	6			

Model 1 includes Tot_AC and Tot_DEC

Coefficients of the equation

Model	Non-standardised	Standard Error	Standardised	t	p
1 (Intercept)	492.30	13.12		37.51	< .001
Tot_Ac	6.33	2.40	10.70	2.63	.05
Tot_Dec	-6.53	2.34	-11.46	-2.79	.04

Table 4
Results of the simple linear regression analysis that accounts for %SHRZ (IL) according to exercise specificity (EL).

Regression model summary					
Model	R	R^2	Adjusted R^2	RMSE	
1	.77	.59	.51	8.89	
Predictive variable: specificity of the exercise Dependent variable: %SHRZ					
ANOVA of the equation					
Model	Sum of squares	df	Mean squares	F	p
1 Regression	593.3	1	593.31	7.35	.04
Residual	403.4	5	80.68		
Total	996.7	6			

Coefficients of the equation					
Model	Non-standardised	Standard Error	Standardised	t	p
1 (Intercept)	40.30	7.59		5.30	.003
Specificity of the exercise	4.60	1.69	.77	2.71	.04

A multiple regression analysis showed that RRmean (IL) is caused by a linear combination of EL variables: Total_Ac and Total_Dec ($R^2 = .84$) (Table 3). In turn, a simple linear regression analysis showed that the behaviour of %SHRZ (IL) was caused by the specificity of the exercises ($R^2 = .59$) (Table 4).

Discussion

The most important finding of this research is the relationship between the IL and EL variables and the specificity of training exercises in men's amateur basketball. IL and EL are different constructs and must be assessed independently (Impellezzeri et al., 2019), suggesting a possible individual regulation of the required IL values according to their relationships with EL and the specificity of the training exercises.

Being able to determine relationships between the IL and EL variables may help to understand the effect of EL on the player and how it affects their recovery, stress or accumulated fatigue (Sansonea et al; 2019). The results obtained in this study point in this direction. In a multifactorial sports context (Carey et al., 2016), the SDNN parameter has evinced a significant correlation with Total Ac_Dec ($p < .05$) which could offer an initial vision of the overall effect of EL on fatigue. The significant relationships found between other variables could open up two channels of action. On the one hand, the possible justification of IL (RRmean) based on the linear combination of Total_Ac and Total_Dec ($R^2 = .84$) would offer a fatigue indicator (Pyne & Martin, 2011) which would make it possible to design specific recovery guidelines for individual profiles (Guillaumes et al., 2018). On the other hand, using a specific IL variable for basketball (Scanlan et al., 2014) such as the %SHRZ ($R^2 = .59$) would make it possible to quantify training exercises and sessions (Sanchez-Ballesta et al., 2019), enabling qualitative (Gabbett, 2016) and preventive (Carey et al., 2016) programming during the season.

Workload management, involving assessing IL and adapting EL to it, is based on the relationship between psychological stress and the exercises performed during training (Scanlan et al., 2014). In the relationship between SHRZ and type of exercise (Rho = .89; $p = .01$), the complexity of the exercise (defined according to the levels of approach of Schelling and Torres, 2013) and the existing constraints (Balague et al., 2014) come into play. Using the exercises' SHRZ values, the behavioural aspect can be modulated (Capdevila et al., 2008) and integrated into the training with the medium- and long-term objective of improving sports performance, avoiding the monotonous nature of loads (Morales et al., 2019) and cognitive-emotional stimuli.

One necessary premise for assessing the applicability of this approach is the independence of the exercises with respect to the session overall and in relation to the IL and EL variables. These results indicate that the variables do not correspond to a specific pattern with regard to the set of exercises that define the training session, while each level of approach is also specific in behaviour for both EL and IL.

This study presents certain limitations. The use of a particular type of technology did not allow connecting several devices at the same time, meaning that it was not possible to record the IL and EL of each exercise in the same session. In turn, the sports setting is open and complex and contact sports such as basketball usually involve uncontrolled variables that increase recording errors or losses, thus reducing study sample sizes. In this regard, amateur sport affects consistency in terms of players' attendance at training sessions and competitions.

Conclusions

In the specific context of an amateur men's basketball team, significant relationships between IL (RRMean, SDNN and %SHRZ) and EL (Total_Dec) and the specificity of the training exercises were observed. In intermittent load sports such as basketball, the recommendation is that IL and EL be assessed independently and in a complementary fashion.

Practical applications

The levels of approach proposed by Schelling and Torres (2013) constitute a valid tool for managing internal and external load control during training. Their applicability may address two objectives. Firstly, programming using EL values would make it possible to approach required IL values. Moreover, the analysis of the IL values prior to training based on HRV would offer individualised, specific and applicable information for managing the optimal EL for training depending on the player's psychological and physiological status.

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