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Influence of analysis focus and playing time on internal average and peak physical demands of professional male basketball players during competition

Influencia del tiempo de juego en las demandas de carga interna pico y promedio en jugadores de baloncesto

Enrique Alonso Pérez-Chao[1].; Alberto Lorenzo[1]; Carlos Ribas[2]; Ruben Portes[3]; Anthony S, Leicht[3]; Miguel A. Gómez[1]

1. Facultad de ciencias de la actividad física y del deporte, Universidad Politécnica de Madrid. España
2. Faculty of Sports Science, European University of Madrid. Spain.
3. Sport and Exercise Science, James Cook University, Townsville. Australia

Abstract

The main aim of this study was identifying the internal demands during competition including the impact of analysis method (i.e., average vs. peak demands). A secondary aim was to analyze the effects of playing time on the internal demands (average and peak). Methods: Twenty-two professional basketball players were monitored during 11 games. The following internal workload variables were recorded as averages (i.e., value per minute considering the entire game) and peak values (i.e., greatest 1-minute window): 1) average Heart Rate (HR), peak HR, average Respiration Rate (RR), peak RR, average Ventilation (VE), peak VE, average VO2 and peak VO2. Results: Significantly higher peak values (very large effect size) for all internal variables were evident when compared to their average demand. Concerning playing time comparison, significantly greater average values were reached for large playing time group (24.54 ± 3.23 min) for all variables compared to small playing time group (14.13 ± 3.78 min). However, non-significant differences were apparent between large playing time and small playing time group at their internal PD. Conclusions: Understanding internal load demands using averages values drastically underestimates the internal peak values of games. Thus, 14 minutes of total playing time (1.5 quarters; ~37% of a game) is enough to expose to the players to internal peak demands.

Keywords: heart rate; peak demands; internal load; worst case scenario; most demanding periods.

Resumen

El principal objetivo del estudio fue comparar las demandas pico con las demandas promedio para diferentes variables de carga interna. El objetivo secundario fue analizar la influencia del tiempo de juego en las demandas de carga interna (promedio y pico). Métodos: Veintidós jugadores profesionales fueron monitorizados durante 11 partidos. Las siguientes variables de carga interna fueron registradas como promedio (e.g., valor por minuto considerando todo el partido) y valor pico (e.g., mayor valor alcanzado en una ventana de tiempo de un minuto): promedio frecuencia cardiaca (FC), FC pico, promedio de respiraciones (RR), RR pico, promedio de ventilaciones (VE), VE pico, promedio de VO2 and VO2 pico. Resultados: Se encontraron valores significativamente más elevados para todas las variables pico comparado con los valores promedio. En relación con la comparación entre los jugadores en función del tiempo jugado, aquellos jugadores que acumularon mayor tiempo (24.54 ± 3.23 min) alcanzaron valores promedio significativamente más elevados para todas las variables analizadas comparado con el grupo que jugó menos minutos (14.13 ± 3.78 min). Sin embargo, no se encontraron diferencias significativas para las demandas pico entre ambos grupos. Conclusiones: Analizando las demandas de carga interna utilizando promedio se subestimas aquellos valores pico. Además, disputar 14 minutos de juego (1.5 cuartos; 37% del partido), es suficiente para ser expuesto a las demandas pico de carga interna.

Palabras clave: frecuencia cardiaca; demandas pico; carga interna; peor escenario; escenarios se máxima exigencia.

Correspondence/correspondencia: Enrique Alonso Pérez-Chao
Facultad de ciencias de la actividad física y del deporte, Universidad Politécnica de Madrid. España
Email: ealonsoperezchao@gmail.com

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Introduction

Basketball is a dynamic, complex, and intermittent team sport that, according to its rules (e.g., court dimension, ball possession time), affords players to develop the ability to perform technical-tactical skills while simultaneously coping with repeated accelerations, decelerations, changes of direction, and jumps (O'grady et al., 2020; Stojanović et al., 2018). Nowadays, monitoring devices allow practitioners to precisely quantify internal and external demands during basketball games (J. L. Fox et al., 2017). In this regard, one of the main objectives during load monitoring is to ensure that an adequate external load is undertaken to stimulate specific physical adaptations (Aoki et al., 2017; Impellizzeri et al., 2018). Further, load monitoring can also document the psycho-physiological responses during exercise or internal load (e.g. rating of perceived exertion, heart rate) (Impellizzeri et al., 2018) to support training practices.

Coaching staff have used both external and internal workload data to better understand the demands of basketball competition and enable the design and implementation of appropriate training sessions that prepare players for game play (Alonso et al., 2020). One of the most crucial issues for high performance sport is the quantification of the most demanding scenarios (MDS) of game-play (Alonso et al., 2020; Alonso Perez-Chao et al., 2021). Quantifying the MDS experienced during games is essential to tailor unique training plans that better prepare players' physical fitness while successfully executing key technical skills (Alonso et al., 2020). To date, many studies have investigated the game demands experienced by basketball players with a focus on the average intensity across entire games (Stojanović et al., 2018). However, examining game demands using averages drastically underestimates the MDS of game-play (i.e. peak demands, high-very high intensity periods or worst-case scenarios) and represents a rudimentary approach (Alonso et al., 2020; Cunningham et al., 2018). The peak demand (PD), defined as the most intense activity experienced by players for a selected variable across a specified timeframe of interest (Alonso et al., 2020), has been quantified for basketball players using many external load variables (e.g. PlayerLoad, distance) and time windows (e.g. 1-min, 2 min) (Alonso et al., 2020; J. Fox, Conte, et al., 2020; J. Fox, Salazar, et al., 2020; Vázquez-Guerrero et al., 2020; Vázquez-Guerrero & Garcia, 2020). In addition, the impact of different factors on the external PD attained by players during basketball games has been investigated, including the effects of player position (Alonso et al., 2020; J. Fox, Conte, et al., 2020), score-line (Vázquez-Guerrero et al., 2020), congested-fixture schedule (Pino-Ortega et al., 2019), age category (García et al., 2021), moment of the game (Alonso Pérez-Chao, Gómez, et al., 2022; J. Fox, Salazar, et al., 2020), playing time (Alonso Perez-Chao et al., 2021) and accumulated playing time prior to external PD (Alonso Perez-Chao et al., 2021). While these previous studies offer useful insight for coaches and practitioners, only one study examined the PD of internal variables experienced by basketball players during games (Alonso Pérez-Chao, Ribas, et al., 2022). This limited understanding of internal PD prevents coaches from developing strategic training and game plans to optimize player and ultimately team performance.

The individualized playing time of basketball players is a key component that coaches can control in order to mitigate player fatigue during key stages of games and optimize team's performance (Edwards et al., 2018). For example, U18 male elite basketball players who undertook less playing time (16.6 ± 2.4 minutes) were able to reach greater peak external PD values aggregated across various time windows (e.g. 30-seconds, 45-seconds, 1-minute, 2-minutes, and 5-minutes) compared to players who completed greater total playing time (25.0 ± 3.4 minutes) (Alonso Perez-Chao et al., 2021). Therefore, controlling playing time may manage player's fatigue levels with associated fatigue mechanisms reducing player's ability to produce a given force or power output (Alonso Perez-Chao et al., 2021). While external PD has been

shown to be impacted by playing time (Alonso Perez-Chao et al., 2021), no study has analyzed the effect of playing time on internal PD which would support coach's player management strategies (e.g., substitutions, use of time-outs) to optimize player outputs during key passages of play.

Based on the limited understanding of the internal demands experienced by basketball players, the main aim of this study was to identify the internal demands of professional basketball players during competition including the impact of analysis method (i.e., average vs. peak demands). A secondary aim was to analyze the effects of playing time on the internal demands (average and peak) experienced during competition. It was hypothesized that the: 1) internal average demands would underestimate the PD; and 2) greatest internal average and peak demands would be obtained by players with less playing time during games.

Material and methods

Participants

Professional basketball players (n = 22, mean ± SD: age 27.2 ± 3.9 years, height 196.7 ± 9.9 cm, body mass 96.8 ± 14.6 kg) from two teams of the Spanish professional basketball League (ACB) volunteered and were monitored during 11 pre-season games. Data from each player was collated from all games with players and their data retained in the final analysis if they completed a minimum of 5 minutes of box-score time, in at least three games. The box-score time was based on the playing time (minutes) derived from the official game records and excluded any passages where the game clock was stopped (e.g., inter-quarter breaks, time-outs, fouls, out-of-bounds). Subsequently, data from two players originally recruited (i.e., n = 24) were excluded from the final analysis, resulting in 22 players being retained in the study. Overall, 100 game records for the 22 players were included in the final analyses. The study was in accordance to the Declaration of Helsinki (Harriss & Atkinson, 2014) and approved by the Institutional Review Board of the Polytechnic University of Madrid, Spain.

Procedures.

This descriptive study was carried out during the 2020-2021 and 2021-2022 ACB pre-seasons where game-play was conducted in line with official FIBA rules (i.e., 4 x 10-minute quarters) and officiated by experienced and qualified referees. During games, each player wore a Firstbeat SPORTS TeamBelt (Firstbeat Technologies Ltd., Jyväskylä, Finland). This 9-axis motion sensor (10g including battery) collected data at 50 Hz with all players familiar with the monitoring technology during training and games. The Firstbeat system was reported to be valid and reliable for the assessment of heart rate, respiratory rate, heart rate variability and oxygen consumption (VO2) (Bogdány et al., 2004). Devices were turned on immediately prior to each game and players wore the same device throughout the study to avoid inter-unit variation in outputs (Castellano et al., 2011; Johnston et al., 2014; Nicolella et al., 2018). After each game, the peak and average value for each variable during consecutive 1-minute windows were extracted from the Firstbeat Sports software (version 1.23.0) and exported into a Microsoft Excel (version 16.0, Microsoft Corporation, Redmond, WA) spreadsheet for further analysis.

Variables.

The following internal workload variables were recorded as averages (i.e. value per minute considering the entire game) and peak values (i.e. greatest 1-minute window): 1) average Heart Rate (HR), peak HR, average Respiration Rate (RR), peak RR, average Ventilation (VE), peak VE, average VO2 and peak VO2 as described previously (Bogdány et al., 2004; Firstbeat, 2017).

Statistical analysis.

The mean, standard deviation (SD), and coefficient of variation (CV) were calculated for each variable. Kolmogorov-Smirnov tests were performed to identify data distribution while Levene's equality of variances test assessed for equal variances in the data. Pending the data distribution, paired samples T-test (normal distribution) or Wilcoxon signed-rank tests (non-normal distribution) were used to identify differences between average and peak demands of each variable (e.g., average HR vs. peak HR). A two-Step Cluster model was employed to classify data/players into groups according to total playing time across games using the box-score time (i.e., large vs. small; average silhouette = 0.7; Table 1) with mean differences between groups identified via independent samples T-test (normal distribution) or Mann-Whitney U tests (non-normal distribution). Magnitude of differences for all comparisons were examined via Cohen's d effect size (ES) and 95% confidence intervals (CI) with interpretations as follows: trivial, 0–0.2; small, 0.2–0.6; moderate, 0.6–1.2; large, 1.2–2.0; and very large, >2.0 (Hopkins et al., 2009). All analyses were conducted using IBM SPSS for Windows (version 23, IBM Corporation, Armonk, New York) and JASP (JASP Team (2020), Version 0.12.2) except for ES, which were calculated using a customized Microsoft Excel spreadsheet (version 16.0, Microsoft Corporation, Redmond, WA).

Table 1. Cluster analysis of identified groups based on playing time during games.

Measure	Large playing time	Small playing time
Total game playing time (minutes)	24.54 ± 3.23	14.13 ± 3.78
Sample size (N)	46	53
Proportion of samples (%)	46.5%	53.5%
Bayesian information criterion	45.42	

Note: Total game playing time presented as mean ± standard deviation for each group; sample size indicates the number of individual game records included across all players.

Results

When comparing average and peak demands, significantly ($p<0.001$) greater values with very large ES were evident for peak values of HR, RR, VE and VO2 (Table 2). For the playing time group comparison, significantly greater values were attained for the large playing time group compared to the small playing time group for average HR ($p < 0.001$; small ES = 0.48), RR ($p < 0.001$; small ES = 0.50), VE ($p < 0.001$; small ES = 0.50) and VO2 ($p < 0.001$; small ES = 0.52). No significant ($p >0.05$) differences, with trivial to small ES (-0.33 – 0.52), were apparent between the large and small playing time groups for any measure of internal peak demand values (Figure 1).

Table 2. Descriptive statistics and effect size (ES) for internal average and peak demands during professional basketball games

Variable		Mean ± SD	%CV	ES (95% confidence interval)
HR (bpm)	**Average**	125.5 ± 10.8	8.6	-6.74 (-8.57 to -4.39); very large
	Peak	187.1 ± 7.1*	3.8	
RR (breaths/min)	**Average**	27.0 ± 3.2	12.0	-5.23 (-6.74 to -3.33); very large
	Peak	47.3 ± 4.4*	9.4	
VE (litres/min)	**Average**	55.1 ± 12.0	21.8	-5.23 (-6.74 to -3.33); very large
	Peak	145.6 ± 22.4*	15.4	
VO2 (ml/kg/min)	**Average**	20.2 ± 3.5	17.1	-8.14 (-10.29 to -5.37); very large
	Peak	48.6 ± 3.5*	7.2	

Note: *p<0.001 vs Average. *Abbreviations:* HR = Heart rate; RR = Respiratory rate; VE = ventilation.

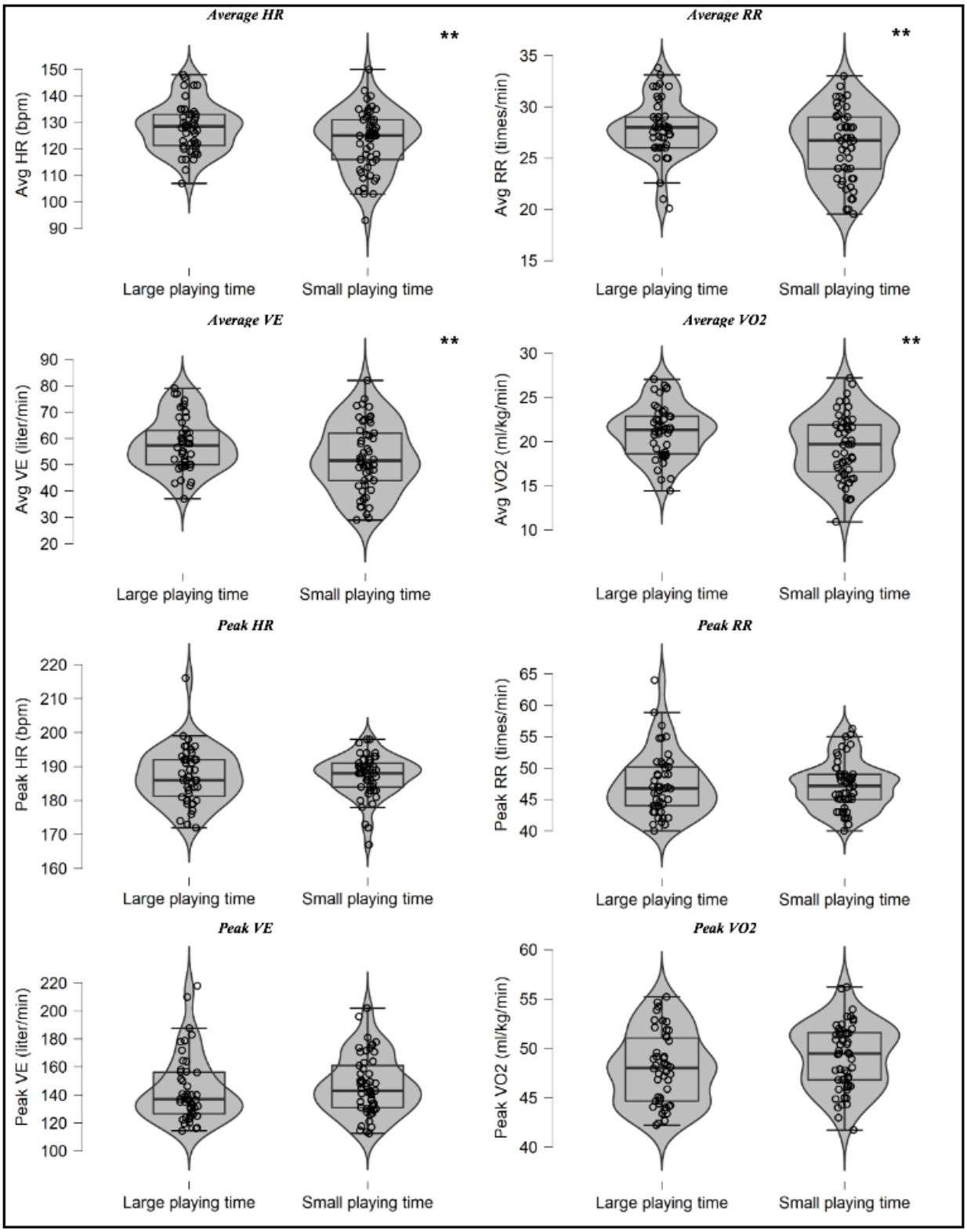

Figure 1. Violin plot mean comparison between Large playing time and Small playing time for all variables at their average and peak. *Note:* ** *Indicates that Large playing time is significantly higher than Small playing time.*

Discussion

The aim of this study was to identify the internal demands of professional basketball players during competition including the impact of analysis method (i.e., average vs. peak demands). A secondary aim was to analyze the effects of playing time on the internal average and peak demand values experienced during professional basketball games. The present study identified significantly greater internal PD values for all variables compared to average game demands. Additionally, greater internal average demand values were exhibited by players who completed more total playing time during games however, internal PD responses were independent of total playing time. Therefore, these results emphasize that the traditional average demands approach underestimates the internal physical demands of basketball players with practitioners encouraged to complement this traditional approach with the novel insights based on the current PD values. Consequently, exposure of players to game internal PD during training sessions may enhance player preparation for competition, irrespective of their total playing time.

The first major finding of the current study was that peak and average values of all internal variables (HR, RR, VE, VO2) indicated distinct game demands for professional basketball players. Many prior basketball investigations have reported similar findings for external load variables with significantly greater external PD compared to external average demands across entire games (Alonso et al., 2020; Alonso Perez-Chao et al., 2021; Vázquez-Guerrero & Garcia, 2020). For example, greater player load (Alonso et al., 2020), distance, high speed distance (>18km/h), number of efforts at high speed distance, distance covered in high-intensity accelerations (>2 m·s-2) and decelerations (<-2 m·s-2) and number of high-intensity accelerations (>2 m·s-2) and decelerations (<-2 m·s-2) (Vázquez-Guerrero & Garcia, 2020) were reported for external PD compared to external average demands for junior male players. Our results add to these prior studies and demonstrated that collectively, examination of internal or external demands using game averages drastically underestimates the peak values of gameplay experienced by players. Given the intermittent nature of basketball competition, the use of average demands is likely to underprepare players to cope with the peak game internal demands (Alonso et al., 2020). Therefore, basketball coaches and practitioners are encouraged to identify the PD of gameplay within their competition to aid the selection of players capable to perform within the competition and/or development of appropriate training sessions to optimize success. Further, coaches may consider the use of high-intensity scrimmages or games as the best training scenario to reach the internal PD experienced by professional basketball players (Alonso Pérez-Chao, Ribas, et al., 2022) and that prepare players optimally for competition.

To address our secondary aim, the present data showed significantly greater average demand values for the large playing time group (24.54 ± 3.23 min) compared to the low playing time group (14.13 ± 3.78 min) for all internal physical variables analysed (HR, RR, VE, VO2). These findings were expected as more playing time would result in a higher external load and subsequent higher psycho-physiological responses during games for players. Further, these greater values likely represented greater exposure of the players to fatigue contributors such as glycogen depletion, muscle damage, action potential interruption, and excitation-contraction coupling failure (Gibson & Noakes, 2004) that may subsequently impact performance. In contrast, players completing less playing time and spending more time on the bench during games experienced less fatigue with lower psycho-physiological responses than players completing more playing time. These differences have clear bearing upon preparation of players before games (e.g., utilize training that replicates these average demands as a minimum) but also management during games to minimize fatigue and enhance performance. For example, coaches may want to consider the use of a substitution rotational plan during games to

economize player's game demands and ensure they are ready for the most intense periods of play (e.g., end of quarter/game) (Alonso Perez-Chao et al., 2021). However, such plans but not be practically conducive for coaches with future studies needed to confirm the impact of such plans for player management and game success.

While playing time significantly impacted upon average internal demands of players, game internal PD values were similar between large and small playing time groups. Therefore, PD responses were independent of total playing time and highlights the need for all players within the team to be prepared optimally for game internal PD. This phenomenon may be attributed to the intermittent nature of the sport where players are exposed to their internal PD at multiple times throughout the game. Additionally, it appeared that as little as 14 minutes of playing time (1.5 quarters; ~37% of a game) was sufficient to expose players to their highest competition demands reenforcing the need for optimal training of all players to cope with these internal PD during games. Future studies may confirm if this phenomenon (i.e., similar internal PD between playing time groups) varies due to the competition level, season stage (e.g., preseason), player sex, or other contextual factors (e.g., score line, game pace, etc.). To our knowledge, no previous studies have examined the effect of playing time on internal PD. However, previous studies have analyzed the effects of playing time on external PD with contradictory results. For example, male, semi-professional basketball players with greater playing time (33.2 ± 1.2 min) attained greater external PD (PlayerLoad) during games than players with less playing time (8.7 ± 6.0 min) (J. Fox, Conte, et al., 2020) In contrast, greater external PD values were attained by players who undertook less playing time (16.6 ± 2.4 min) compared with those who completed greater total playing times (25.0 ± 3.4 min) (Alonso Perez-Chao et al., 2021). Therefore, future studies are needed to investigate further the impact of playing time on both internal and external PD and its relevance to coach's strategic plans, training preparation of players and game success.

The current study employed a considerable sample of professional basketball players at a time of high player preparation for competition (i.e., pre-season). However, several limitations encountered should be considered when interpreting our results. Firstly, the peak values identified were the highest values experienced by players against their pre-season opposition with these potentially being lower than their factual maximal values. Additionally, these findings may not be applicable to non-professional basketball teams or other phases of the competition season with future studies recommended to extend these results to other contexts.

Our findings offer potential practical applications in many ways for basketball practitioners. First, understanding internal game demands using averages drastically underestimates the internal peak demands. Therefore, players should be trained appropriately with consideration of these potential multiple peak values rather than average game demands or intensities. The use of focused scrimmages (~14 minutes) may be an ideal method to expose player to their peak requirements in preparation for competition. Secondly, as internal peak responses were independent of total playing time, but average values were greater for players with greater playing time, coaches could use this information to plan appropriate compensatory strategies. For example, players with large playing times/loads may undertake recovery activities while those with small playing times/loads may undertake additional training activities to maintain/enhance game readiness. Understanding both peak and average game demand values along with other additional factors (e.g., fitness and fatigue status, player wellness, material and human resources, age, position, previous injuries, team culture, club culture, motivation, or schedule congestion) by team staff may optimize training preparation, game performance and ultimately team success.

Conclusions

The current study demonstrated that recording game internal load demands using average values drastically underestimated the PD. Additionally, higher internal average values but not peak responses were dependent upon total playing time during games. Given the intermittent nature of basketball competition incorporation of scrimmages (e.g., 14 minutes of total playing time) may ideally expose players to competition demands and allow optimal training of players to cope with these internal PD during games.

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