

ORIGINAL RESEARCH

The influence of fatigue on internal and external load using game-based drills in junior and adult male basketball players

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Abstract

Background: Fatigue demonstrated by decreasing performance seems to occur towards the ends of periods of matches and can lead to a win or loss of the match. **Objective:** This study aimed to assess the influence of fatigue on internal and external load using game-based drills in junior and adult male basketball players. **Methods:** A total of 50 elite basketball players participated in this study. Every participant was monitored by the Team Pro Polar system to find out heart rate and activity demands during a game-based drill. Mixed analysis of variance 2×4 was used. **Results:** Significant interactions between age category and playing quarter were found for distance covered ($p = .001$, $\eta_p^2 = .25$). Significant interactions between age category and playing quarter were found for relative time in zone 3 (running, $p = .013$, $\eta_p^2 = .25$) and zone 4 (high-intensity running, $p = .004$, $\eta_p^2 = .34$). When comparing the last three minutes of quarters, a significant main effect was found for playing quarter, when the distance covered ($p = .001$, $\eta_p^2 = .47$) significantly decreased. A significant main effect was found for playing quarter, whereby relative time spent in zone 3 ($p = .012$, $\eta_p^2 = .09$; quarter 1 vs. 4: $p = .044$) significantly increased, and in zone 4 decreased ($p = .001$, $\eta_p^2 = .29$, moderate effect; quarter 1 vs. 4: $p = .010$). When comparing heart rate and activity demands during the last three minutes of playing quarters, the significant main effect for the age category was found in distance covered ($p = .004$, $\eta_p^2 = .27$). It was greater in adult male players compared to junior players. **Conclusions:** The fatigue affects the distance covered, and intensity of activity demands during the last three minutes of quarters, but not the heart rate response of players.

Keywords: heart rate, activity demands, specific conditioning

Introduction

Modern basketball training brings a greater integration of technology for player monitoring during training or match-play. Combined monitoring of external demands and internal responses supplies a comprehensive insight into determining players' readiness and identifying fatigue during match-play (Akubat et al., 2014). These outcomes can be used to design game-specific conditioning drills and training plans. The implementation of effective training strategies is essential to promote favourable physiological adaptations that improve performance and minimize the risk of developing non-functional overreaching, illness, and/or injury.

A number of researchers have sought to quantify the activity demands and physiological responses encountered during basketball match-play (Ben Abdelkrim et al., 2007; Narazaki et al., 2009; Scanlan et al., 2012). The existing data demonstrate that basketball gameplay is highly intermittent and relies upon significant energy contributions from both the anaerobic and aerobic metabolic pathways (Hůlka et al., 2013). Previous review (Stojanović, Stojiljković, et al., 2018) suggests that basketball gameplay is comprised of short bouts of explosive tasks (e.g., accelerations,

decelerations, shuffles, and jumps) interspersed with low-to moderate-intensity periods. Furthermore, mean heart rate (HR) responses between 82% and 95% of maximum HR (HR_{max}) have been observed during basketball play (Stojanović, Aksović, et al., 2018). Despite the growing body of evidence detailing the activity demands and physiological responses encountered during a basketball match, the precise data concerning temporal changes in activity demands and internal response relative to playing level, are not well established and therefore the optimal training, preparatory, and recovery approaches for players are likely still to be developed.

To date, several studies have quantified temporal changes in activity demands and physiological response during match-play in male basketball players. However, with inconsistent findings. In particular, a relatively consistent workload across playing periods has been reported in semi-professional female basketball players (Matthew & Delextrat, 2009; Scanlan et al., 2015). On the other hand, Ben Abdelkrim et al. (2007) and Janeira and Maia (1998) reported significant decreases in high-intensity activity and HR responses with game progression in elite junior and professional adult male basketball players.

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Similarly, nonsignificant large-to-very large reductions in high-intensity work and shuffling demands and increases in dribbling activity have been observed with game progression in professional adult male players (Scanlan et al., 2015). The authors postulated the variability in high-intensity activity and HR responses across playing periods were reflective of depleted glycogen and high-energy phosphate stores contributing to player fatigue (Ben Abdelkrim et al., 2007; Scanlan et al., 2015). However, indirect suppositions regarding player fatigue during gameplay might be misleading, as many variable factors may affect player demands, including playing pace, stoppages, and player substitutions.

Variations in match stoppages, playing pace, and substitutions across studies make it difficult to definitively understand temporal changes in activity demands and HR responses to quantify fatigue patterns in players. Game-based drills might be an effective form to overcome these limitations. Namely, a game-based drill provides better control of numerous variable factors (e.g., stoppages, player substitutions, playing pace) simultaneously providing the opportunity to assess HR response and activity demands. Careful control of modifiable factors with simultaneous monitoring of HR response and activity demands is important in understanding fatigue.

Khoramipour et al. (2021) recommended coaches to include increased awareness of the changing physical demands across quarters and match time flowed. Carling et al. (2008) and Bangsbo et al. (2007) found that fatigue demonstrated by decreasing performance seems to occur towards the ends of periods of matches and can lead to a win or loss of the match. Despite we did not find the analysis of workload during quarters in basketball. In soccer, Mohr et al. (2005) found a significant decrease in workload during the last third of each period. We did a similar choice to analyse the last third of the game-based drill.

Provision of age-specific data is also important when quantifying temporal changes in the HR responses and activity demands. Previous research has shown that younger players (U14) possessed lower physical fitness and performed less high-speed running during simulated matches compared to older players (U16 and U18; Castillo et al., 2021). To date, no research has compared the activity demands and HR response relative to playing period across different age categories. Comparison of activity demands between different age categories would provide important data for the development of specific training plans and transitioning of players to the senior level. Therefore, this study aimed to assess the influence of fatigue on HR response and activity demands using game-based drills in junior (U18) and adult male basketball players.

Methods

Experimental design

A within-subject observational study design was used to assess the influence of cumulative fatigue on HR response and activity outputs across game-based drills. Every participant completed a laboratory treadmill test to *vita maxima* to determine HR_{max} . The study was conducted

over a two-week period. Every participant completed two sessions at the team's home facility. During the first session, participants were familiarized with wearing the chest strap (Polar Team Pro, Kempele, Finland) and the rules of the game-based drill, and the signal for GPS was checked. The second session was used to apply the game-based drill. Both monitored sessions took place on Mondays, in the afternoon, with a rest period of 72 hours from the last practice. Each session started with a 20-min standardized warm-up consisting of moderate-intensity jogging, static and dynamic stretching, and accelerative running bouts. Each participant completed a 4 × 10-min game-based drill, with a 5-min half-time break and 2-min interquarter breaks. Scores were annulled at the beginning of each quarter, to ensure equal psychological (e.g., motivation) and tactical approach (e.g., playing pace) to all periods. Free throws were not executed, and coaches did not have any time out to ensure the same playing time in every quarter and part of the quarter. Coaches were instructed to maintain motivational, technical, and tactical instructions as during the official matches as well as players were instructed to play at their best as they would during a competition. HR response and activity demands were analysed separately across all quarters and the last 3 min of each quarter.

Participants

Fifty elite, male basketball players from five teams competing at the highest competitive level in Czech Republic (National Basketball League) volunteered to participate in this study. Players were classified according to their chronological age (Stojanović, Aksović, et al., 2018) as seniors ($n = 20$; 12 from backcourt and 8 from frontcourt; age 24.9 ± 6.8 years; height 191.0 ± 18.8 cm; body mass 91.2 ± 26.9 kg) and juniors ($n = 30$; 23 from backcourt and 7 from frontcourt; age 17.7 ± 0.8 years; height 184.7 ± 9.24 cm; body mass 77.3 ± 6.9 kg). All participants were recruited from the same competitive level and has at least ten years of experience. All participants trained at least five times a week with their teams with two matches every second weekend for juniors and one match every weekend for seniors. Only participants free from injury and medical difficulties were included in the study. Participants were informed about the aims of the study including any risks, discomforts, and benefits and provided written informed consent (by parents if under 18 years of age). The study was approved by the institutional ethic committee (FTK_14/2020) which followed the Declaration of Helsinki.

Heart rate response

Heart rate was continuously recorded in 1s intervals during the game-based drill using a Polar Team Pro System (Polar Electro, Kempele, Finland), whereby subjects had HR monitors affixed to their chest at the level of the xiphoid process. Heart rate responses were presented relative to each subject's individualized HR_{max} , which was determined by laboratory measurement. Raw data from HR monitors were exported into Microsoft Excel (Version 16.35; Microsoft, Redmond, WA, USA) to calculate mean HR and percent of time spent in the following HR intensity zones (Vaz et

al., 2016): low ($< 75\% \text{HR}_{\text{max}}$), medium ($75\text{--}84\% \text{HR}_{\text{max}}$), high ($85\text{--}95\% \text{HR}_{\text{max}}$), and maximal ($> 95\% \text{HR}_{\text{max}}$).

Activity demands

Activity demands were measured using a 10 Hz Polar Team Pro device (Polar Electro, Kempele, Finland). Raw data were exported into Microsoft Excel (Version 16.35; Microsoft, Redmond, WA, USA) to calculate different activity intensities according to (Hůlka et al., 2013): zone 1 (standing, $\leq 0.30 \text{ km}\cdot\text{h}^{-1}$), zone 2 (walking or jogging, $0.31\text{--}3.60 \text{ km}\cdot\text{h}^{-1}$), zone 3 (running, $3.61\text{--}10.80 \text{ km}\cdot\text{h}^{-1}$), zone 4 (high-intensity running, $10.81\text{--}18.00 \text{ km}\cdot\text{h}^{-1}$), zone 5 (sprinting, $> 18.01 \text{ km}\cdot\text{h}^{-1}$). According to Fox et al. (2019), the Polar device underestimates speed (from 3.25% to 8.0% depending on intensity) and distance covered (from 3.37% to 10.25% depending on intensity) in indoor measurement.

Statistical analysis

Data analyses were performed using Statistica (Version 13; StatSoft, Tulsa, OK, USA). Mean and standard deviation were calculated for each outcome measure. Normality and homogeneity of all data were verified with the Kolmogorov-Smirnov and Levene's tests. A 2×4 mixed analysis of variance with one within-subjects factor (quarter), and one between-subjects factor (age category) was used to assess inter-quarter differences across both age groups. When a significant interaction and main effect of the quarter were observed, the pairwise comparisons were examined using Tukey post hoc tests. Partial eta-squared (η_p^2) was utilized as a measure of effect size for each analysis of variance, and values were interpreted as *small effect* ($.01 \leq \eta_p^2 < .06$), *medium effect* ($.06 \leq \eta_p^2 < .14$), and *large effect* ($\eta_p^2 \geq .14$). Statistical significance was set at $p < .05$.

Results

The HR responses and activity demands encountered by senior and junior basketball players during game-based drills across playing quarters are shown in Table 1. When comparing interaction between age category and playing quarter we did not find any significant difference. Similarly, we did not find any significant difference in the main effect of playing quarter for HR and activity demands. The significant main effect for age category was found for mean HR (higher for junior players, $p = .027$, $\eta_p^2 = .14$), relative time spent in zone 1 (higher for junior players, $p = .041$, $\eta_p^2 = .10$) and zone 5 (lower for junior players, $p = .017$, $\eta_p^2 = .19$).

The HR responses and activity demands encountered by senior and junior basketball players during game-based drills across the last 3 min of quarters are shown in Table 2. When comparing HR and activity demands during the last three minutes of playing quarters, a significant interaction between age category and playing quarter were found for distance ($p = .001$, $\eta_p^2 = .25$). Post hoc tests comparing inter-quarter changes showed significant decrease in junior (quarter 1 vs. 4: $p = .001$) and senior players (quarter 1 vs. 4: $p = .001$; quarter 1 vs. 3: $p = .001$;

Table 1 The heart rate responses and activity demands experienced during game-based drills across quarters in senior and junior basketball players

Outcome measure	Senior				Overall	Junior				Overall
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		Quarter 1	Quarter 2	Quarter 3	Quarter 4	
Heart rate										
HR _{mean}	82.5 ± 4.5	82.0 ± 5.4	81.4 ± 4.9	82.8 ± 4.9	79.1 ± 15.5	86.2 ± 3.5	85.9 ± 3.9	82.3 ± 7.9	83.0 ± 6.8	85.1 ± 4.8*
< 75% HR _{max} (%)	12.6 ± 10.1	12.6 ± 15.2	14.8 ± 15.2	12.0 ± 19.1	12.5 ± 16.8	10.5 ± 8.7	9.6 ± 8.6	13.5 ± 15.2	13.1 ± 12.8	8.4 ± 11.6
75–84% HR _{max} (%)	38.7 ± 24.8	41.2 ± 22.2	41.9 ± 18.1	37.1 ± 23.8	41.4 ± 20.3	22.1 ± 16.6	23.2 ± 12.1	27.7 ± 17.6	28.2 ± 11.0	26.6 ± 19.2
85–95% HR _{max} (%)	47.0 ± 31.8	45.7 ± 25.2	43.2 ± 21.7	49.8 ± 29.3	45.1 ± 15.9	60.5 ± 16.6	61.3 ± 21.9	57.4 ± 25.3	56.8 ± 24.0	60.0 ± 18.2
>95% HR _{max} (%)	1.8 ± 1.2	0.5 ± 1.3	0.5 ± 0.8	1.1 ± 3.8	1.6 ± 3.5	5.9 ± 1.7	5.9 ± 4.4	1.4 ± 3.1	2.0 ± 5.1	5.1 ± 13.1
Activity demands										
Distance (m)	991.3 ± 160.8	1015.9 ± 170.9	946.1 ± 192.7	969.7 ± 185.3	4068.2 ± 284.5	982.9 ± 159.5	904.4 ± 109.4	882.2 ± 138.1	896.3 ± 155.3	3814.9 ± 290.8
Zone 1 (%)	7.1 ± 6.9	7.4 ± 5.3	7.9 ± 6.3	8.4 ± 6.0	7.2 ± 4.3	11.9 ± 12.8	12.5 ± 10.8	16.2 ± 15.3	10.7 ± 6.8	13.9 ± 6.6*
Zone 2 (%)	14.3 ± 5.0	15.6 ± 5.0	14.8 ± 5.9	15.3 ± 5.8	14.1 ± 9.2	14.9 ± 3.7	13.2 ± 2.7	13.6 ± 3.4	14.1 ± 4.1	13.8 ± 3.9
Zone 3 (%)	61.8 ± 6.0	58.9 ± 5.9	58.1 ± 6.6	56.2 ± 7.2	59.7 ± 16.4	58.8 ± 11.8	58.8 ± 8.4	55.9 ± 11.9	57.9 ± 12.1	57.3 ± 16.0
Zone 4 (%)	10.5 ± 5.4	10.2 ± 4.9	11.2 ± 5.9	10.1 ± 5.2	10.8 ± 10.0	12.7 ± 4.9	13.6 ± 5.0	11.9 ± 4.5	12.9 ± 5.6	12.6 ± 21.4
Zone 5 (%)	7.1 ± 6.9	7.4 ± 5.3	7.9 ± 6.3	8.4 ± 6.0	7.2 ± 4.3	1.6 ± 1.5	1.9 ± 1.3	2.2 ± 4.2	2.9 ± 6.8	1.5 ± 1.1*

Note. *Significantly different between seniors and juniors.

quarters. A gradual significant decrease in high-intensity activity and distance covered was detected by Khoramipour et al. (2021) for top Iran male basketball players.

For a more detailed analysis of cumulative fatigue, we explored the last third of each quarter to determine the influence of fatigue. The fatigue development was not to be expressed by HR changes. But, with the same internal response of players, the external performance expressed by activity demands was decreased. This significant change was represented by decreasing in the total distance covered during the last three minutes of quarters. The measured decrease of distance covered was connected to transfer time from higher intensity activity zone 4 to zone 3. These results were more pronounced for less experienced players and showed the necessity of specific basketball conditioning.

According to Caprino et al. (2012), time-motion data reveal cumulative fatigue of players during a basketball match. Fatigue manifestation characterized by decreasing activity demands was also published in soccer by Carling et al. (2008) and Barros et al. (2007), or Sirotic et al. (2009) in rugby.

It has been established that high-intensity efforts are critical to match performance (Duffield & Coutts, 2011). Similarly, the pacing strategies are apparently used to maintain the quality of crucial high-intensity efforts during the whole match at the expense of the transfer of medium intensity activity to lower ones (Aughey et al., 2014; Johnston et al., 2014; Matthew & Delestrat, 2009). This fact can restrict players to keep movements mainly without the ball. These movements allow offense to be played more variably and gives players and coaches more options to score. Similar tendencies were found in football by Castagna et al. (2003).

Caprino et al. (2012) showed a significant effect of match time-motion data and repeated sprint ability. This ability to perform more intensive activities or shorten the time to recover is connected to the amount of fatigue. This fatigue can be considered a causal indicator of specific endurance preparedness of the player to give an adequate physical performance during the whole match (Impellizzeri & Marcora, 2009). It can lead coaches to determine specific endurance preparedness for the competition part of the season.

The results showed possible insufficiency of using HR measures without the support of external performance data to detect the size of fatigue during a match. We found significantly higher mean HR in junior male players than in adult male players during playing quarters. It was connected with less relative time spent in zone 1 and more time in zone 5 of senior players. A deeper analysis of the ends of quarters showed significantly lower distance covered by junior basketball players.

We found only one study, which compares HR and activity demands according to age. Castillo et al. (2021) showed an increasing trend of high-speed running and sprinting with growing age. We found no research has compared the activity demands and HR response relative to playing period across different age categories. It seems greater playing experience showed higher work volume of

male basketball players with less internal response from the organism. The reason could be better specific preparedness of experienced players, thanks to higher movement economy and better application of pacing strategies. The second reason could be that senior players tend to be more tactical than junior players.

As a limit of the study, we consider that results may not be representative of teams of different ages, gender and playing levels. Concurrently for deeper usage of results to make a more individualised training process post differences should be considered. Equally score and tactical aspects were not reflected. The reliability of measurement should be performed. The last limit we consider is the underestimation of speed.

Conclusions

Manifestations of fatigue during the last parts of the quarter of the basketball match are mainly reflected in the decline of physical demands, thus mainly decreasing of distance covered and shifting the relative time to less intensive activity zones. The quality of specific endurance preparedness could be verified by the declining rate of measured manifestations of fatigue.

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Conflict of interest

The authors report no conflict of interest.

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