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Breaking Down the 3 × 3 Basketball Game: How Tournament Phase, Game Outcome, and Final Score Margin Impact Physiological, Perceptual, and Mental Demands

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Purpose: To evaluate heart rate (HR), perceived exertion, and mental effort (ME) in 3 × 3 male basketball games according to tournament phase, game outcome, and final score margin. ***Methods:*** Forty-one adult male 3 × 3 players (tiers 2–3) were monitored across 3 tournaments. Microsensors quantified average HR and peak HR responses during gameplay. Additionally, ratings of perceived exertion (RPE) and ME scores were collected after games. Separate linear mixed models analyzed the effect of tournament phase (group, round of 16, quarterfinals, semifinals, and finals), game outcome (won and loss), and final score margin (balanced and unbalanced) on HR responses, RPE, and ME. ***Results:*** No effects of tournament phase, game outcome, or final score margin were found for average HR ($P = .834$) or peak HR ($P = .566$). RPE was higher in semifinals than group ($P = .019$, *small*) and round of 16 ($P = .007$, *small*) games. RPE was also higher in lost games compared to won ($P = .028$, *small*) and in balanced games compared to unbalanced ($P = .027$, *small*). Similarly, ME was higher in semifinals and finals when compared with group games ($P < .05$, *small*) and round of 16 games ($P < .05$, *moderate*). ME was also higher in balanced games when compared to unbalanced games ($P = .029$, *small*), while no difference was found between won and lost games. ***Conclusion:*** In 3 × 3 basketball, HR responses remain constant across different tournament phases, game outcomes, and final score margins, while perceptual and mental demands are greater in the knockout rounds and balanced games. It is recommended that coaches prepare players appropriately for the greater perceptual and mental demands posited by balanced and knockout stage games.

Keywords: team sports, athlete monitoring, internal load, mental fatigue, Olympic sports

Three-on-three basketball is an official sport sanctioned by the International Basketball Federation (FIBA) that is gaining popularity and attention from fans and sport-performance experts. Since the official rules were developed in 2010, 3 × 3 basketball has obtained milestone recognition with its inclusion in the Tokyo 2020 Olympic Games, which continued at the Paris 2024 Games, and will follow in the next Los Angeles 2028 games. Currently, 182 national federations compete in official national, continental, and international (world) competitions organized by the FIBA 3 × 3 federation. Considering the increasing popularity of basketball the body of sport sciences research on 3 × 3 basketball has also grown. Previous research has analyzed the physical[1,2] and technical–tactical[3,4] demands of 3 × 3 basketball, with a recent systematic review[5] providing insights into the specific demands of the game. 3 × 3 basketball is highly intermittent, characterized by fast paced and highly demanding neuromuscular actions (ie, changes of direction, acceleration, decelerations, and jumps). Compared with 5 × 5 basketball,[2,5] the intensity demands during live play and the neuromuscular actions are higher in 3 × 3.[6,7] Regarding physiological demands, previous studies described the absolute heart rate (HR) responses (ie, measured in beats per minute) during male 3 × 3 gameplay (164 [12] beats·min^{-1})[1,8]; however, knowing the relative HR responses of player (ie, in percentage of the maximum [HR_{max}]) would provide more detailed information for practitioners for accurate training prescription, since relative HR is more closely related to the athlete's maximal oxygen consumption.[9] To the best of our knowledge, only one study[10] monitored relative HR responses during 3 × 3 games (90.8% [3.8%] of the peak HR); in addition, relative peak HR responses have not been previously monitored, underscoring the need for further research on physiological demands.

Team sports, including 3 × 3 basketball, also impose significant perceptual-cognitive demands. When individuals use their mental resources to reach a given level of performance during a task, such as competitive sports, perceptual-cognitive demands are generated.[11] During 3 × 3 basketball gameplay, players need to maintain a high level of sustained attention, undergo continuous decision making, collaborate with teammates while also interacting and reacting to the action of opponents.[12] Noticeably, these perceptual-cognitive processes occur at a rapid pace, defined by short (6–8 s), but numerous (n = ~85) ball possessions[5] which may impose a considerable mental load. This is particularly true considering that time pressure significantly amplifies the perceived demands of a given task, including basketball gameplay.[11,13,14] Additionally, 3 × 3 tournaments require athletes to participate in multiple, physically, and mentally demanding games during the

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same day (up to 2 per day), placing considerable overall demands on players that might lead to fatigue and impaired performance.[15,16] Therefore, knowing the physiological and perceptual-cognitive demands of this novel sport would provide deeper insights, which can inform practitioners for better training prescription, talent identification, and improve players' preparedness for the wide-ranging demands of tournaments. While previous studies have assessed perceived exertion scores,[1,8,10,17] no study assessed the perceptual-cognitive demands (ie, mental effort [ME] or mental fatigue) induced by 3×3 games.

Furthermore, a gap in previous 3×3 basketball research is represented by the limited amount of information on how contextual factors influence the demands imposed on players. It is widely agreed that performance and load information should be contextualized[18,19] for better description of the basketball player's performance profile. However, only few studies have addressed the influence of contextual factors, such as tournament phase,[1,7,17] and game outcome.[7] Specifically, physical and physiological load variables appear to be, overall, maintained across the different tournament phases,[1,2,7] while game outcome was assessed only by Ferioli et al,[7] who reported no difference in time-motion analysis parameters between won and lost games. Furthermore, no study has addressed the influence of score-line margin, which has been shown to affect the demands experienced by 5×5 basketball players.[18] Furthermore, the perceptual-cognitive demands might also be affected by the tournament phase, game outcome, and score-line margin; however, no previous research has investigated these aspects. Therefore, the aim of this study is to investigate the physiological, perceptual, and mental demands imposed by 3×3 basketball games according to tournament phase, game outcome, and final score margin.

Methods

Subjects

A total of 41 adult male basketball players: (mean [SD]: age: 23.4 [4.7] y, stature: 189.5 [9.7] cm, body mass: 86.1 [11.1] kg; competitive standard[20]: tiers 2–3) participated in this study. The sample is substantially greater than the one provided by our post hoc power analysis (performed on G*Power, version 3.1), which indicated that a sample of 21 subjects was needed for a repeated-measures model with an estimated effect size of 0.25 and a statistical power of 0.80. All players competed in 5×5 Italian basketball leagues, ranging from regional to national-level competitions. Data from players who were injured or ill along the tournament durations were excluded, for a total of 172 individual data points collected. Before the start of the data collection, each player was informed about the monitoring procedures and signed a consent form. The institutional review board of the University of Rome "Foro Italico" approved the project (approval number: CAR 208/2024).

Study Design

An observational study with repeated measures was performed. Players were monitored across 3 official 3×3 basketball tournaments organized by the Italian Basketball Federation. Each tournament took place over 2 days (June 15–16, June 21–22, and June 28–29, 2024), with the first day dedicated to the group stage games (n = 3 for each participating team) and the second day dedicated to the knock-out stage. Games were played according to the official 3×3 basketball rules set by the International Basketball Federation (FIBA). All games were played outdoors, with average duration, temperature, and humidity of 11.4 ± 1.4 minutes, 26.0 °C, and humidity 53.6%, respectively.

Methodology

During all games, players wore Firstbeat Sport sensors (Firstbeat Technologies Oy) firmly affixed to their chest roughly at the base of the sternum via textile straps. The Firstbeat Sports device features a valid and reliable[21] HR monitor, which continuously assesses the players' physiological responses during games. HR_{max} was set based on the player's peak HR value reached across the tournaments. Two indicators were computed: HR_{mean} (average HR across the game, calculated in percentage of the HR_{max}) and HR_{peak} (peak HR reached during the game, calculated in percentage of the HR_{max}).[5,22] Players were tracked across the whole duration of games, including stoppages and bench time.

Within 10 minutes after each game, an experienced sport scientist individually asked players to report their rating of perceived exertion (RPE) score using the CR-10 scale.[23] Additionally, players reported the ME required by the game just finished using a 100-mm visual analog scale. The scale reported 2 verbal anchors: *none* at all at the initial side and *maximal* at the end one.[16,24] Two weeks before the start of the tournaments, players received an informative sheet providing definitions and examples of RPE and ME. On the tournament start day, players were asked regarding the differentiation of the 2 constructs and offered clarification by the research staff if any confusion was present.

The following contextual factors were evaluated. Games were classified according to the competition stage[1,7] as group games (n = 26), round of 16 (n = 6), quarterfinals (QF; n = 6), semifinals (SF; n = 5), or finals (n = 2). The game outcome (win and lose) was registered for each team. To classify games according to the final score margin,[18,19] a 2-step cluster analysis was performed, which produced 2 significantly different clusters identifying balanced (≤7 points; n = 34) and unbalanced (≥8 points; n = 12) games.

Statistical Analysis

Variables are presented as estimated marginal mean ± standard error (SE). Statistical analyses were performed using Jamovi (version 2.3; https://www.jamovi.org/), with the α level set at .05. Linear mixed models were computed to assess the effects of competition stage, game outcome, and score margin on HR_{mean}, HR_{peak}, RPE, and ME responses of players. Players were inserted in the models as random effect to account for repeated measures. Akaike's Information Criterion (AIC), F, P values, and estimated marginal means (mean ± SE) were reported for each model. Post hoc Bonferroni comparisons were computed, with effect sizes (ESs) calculated as Cohen d and interpreted as <0.20, trivial; 0.20 to 0.59, small; 0.60 to 1.19, moderate; 1.20 to 1.99, large; and > 2.0, very large.[25]

Results

Figures 1 and 2 present the results across tournament phases, while Tables 1 and 2 present the results according to game outcome and final score margin, respectively.

Regarding HR_{mean} (AIC: 893.493), no effect was found for tournament phase (F: 0.741, P = .566), game outcome (F: 0.315, P = .576), and final score margin (F: 1.093, P = .298). Similarly, no significant effect for HR_{peak} was found according to tournament

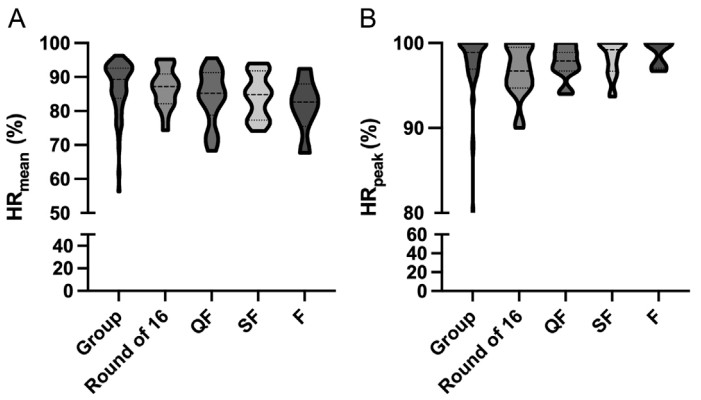

Figure 1 — Physiological responses across tournament phases. (A) HR_{mean} (in percentage) and (B) HR_{peak} (in percentage). F indicates finals; HR_{mean}, mean heart rate; HR_{peak}, peak heart rate; QF, quarterfinals; SF, semifinals.

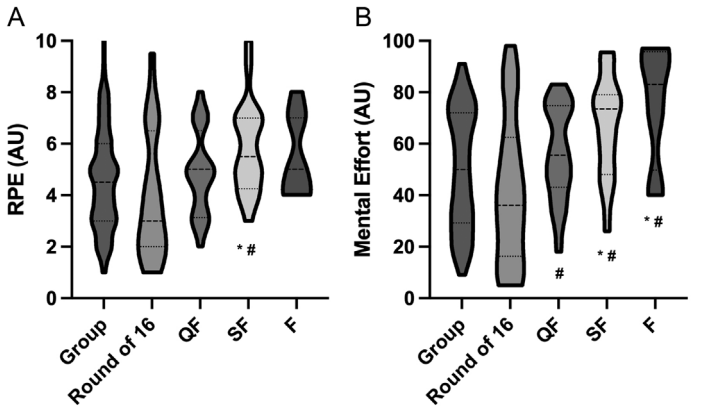

Figure 2 — Perceptual-cognitive responses across tournament phases. (A) RPE and (B) mental effort. *Significantly higher than group. #Significantly higher than round of 16. AU indicates arbitrary units; F, finals; QF, quarterfinals; RPE, rating of perceived exertion; SF, semifinals.

Table 1 Results for the Dependent Variables According to Game Outcome

	Won games	Lost games	*P*	ES
HR_{mean}, %	85.0 ± 1.4	84.2 ± 1.5	.576	0.03, trivial
HR_{peak}, %	97.6 ± 0.8	97.3 ± 0.6	.720	0.07, trivial
RPE, AU	4.8 ± 0.3	5.4 ± 0.3	**.028**	0.49, small
Mental effort, AU	58.1 ± 4.0	58.5 ± 4.3	.651	0.22, small

Abbreviations: AU, arbitrary units; ES, effect size; HR_{mean}, mean heart rate; HR_{peak}, peak heart rate; RPE, rating of perceived exertion. Note: Significant effects are represented in bold.

phase (*F*: 0.364, *P* = .834), game outcome (*F*: 0.133, *P* = .720), and final score margin (*F*: 1.833, *P* = .178).

RPE (AIC: 679.094) was significantly different between tournament phases (*F*: 3.535, *P* = .003) and final score margin (*F*: 4.763, *P* = .027), while no change was detected according to the game outcome (*F*: 0.373, *P* = .542). Precisely, RPE was higher in semifinals than group and round of 16 games (*P* < .05, ES: 0.50–0.58, *small*) and higher in balanced games compared with unbalanced (*P* = .027, ES: 0.36, *small*). Regarding ME (AIC: 1446.921), significant differences were found across tournament phases (*F*: 6.560, *P* ≤ .001) and final score margin (*F*: 4.973, *P* = .029), while no difference was found according to the game outcome (*F*: 0.207, *P* = .651). Specifically, ME was higher in semifinals and finals when compared with group games (*P* < .05, ES: 0.49–0.58, *small*) and round of 16 games (*P* < .05, ES: 0.62–0.70, *moderate*), and higher in balanced games when compared to unbalanced games (*P* = .029, ES: 0.35, *small*).

Discussion

This study evaluated the physiological and perceptual-cognitive demands of official 3 × 3 basketball tournaments across tournament phases, as well as according to game outcomes and final score margins. Although average and peak cardiovascular responses did not show significant variation, perceived exertion and ME were significantly higher in semifinals than to group and round of 16 games, and in balanced games compared to unbalanced ones.

The HR_{mean} values during 3 × 3 games in this study (~85% HR_{peak}) are similar to those of previous research. Specifically, only one study[10] assessed relative HR values during 3 × 3 gameplay and found average values of 91% during live time (ie, excluding breaks and bench time). Given that our study monitored players continuously, including breaks and bench time, the lower HR_{mean} values (approximately 85%) can be explained. Furthermore, the mentioned study[10] did not specify how the HR_{max} was obtained, with potential discrepancies between results obtain using different methodologies (ie, HR_{peak} obtained from maximal fitness testing[26] or during training and competition).[27] Compared with 5 × 5 basketball, the current study values fall within those reported in a previous systematic review[28] (81%–95% of the max during live play). Noticeably, our players' HR responses did not vary according to tournament phases, game outcome nor score-line margin. In fact, our findings agree with previous studies in both 3 × 3[1,8] and 5 × 5 basketball[18] for which contextual factors did not influence cardiovascular responses. We speculate that this fact could be explained by similar external loads imposed by games played under different contextual factors, as found by a previous study,[1] which would lead to similar internal responses.[29] Therefore, average cardiovascular responses in 3 × 3 basketball remain constant across tournament phases, game outcomes, and score-line margins.

To our knowledge, no previous studies assessed peak HR responses in 3 × 3 basketball players. Our results suggest that, during games, 3 × 3 players reach considerable cardiovascular responses (~97% HR_{max}). In line with what found for HR_{mean}, HR_{peak} responses did not vary across tournament phases, game outcomes, and final score margins, suggesting that physiological responses are not influenced by contextual factors. However, HR_{peak} was moderately higher (while not statistically significant) in final games compared with group games, which may reflect the increased effort and higher psychoemotional demands associated with such decisive and important games, or the possible accumulation of fatigue across the tournament length leading to higher HR responses.

Regarding RPE, the current study values (4.4–5.7 AU) are similar to those reported in a previous systematic review on 3 × 3[5] which reported RPE values between 5.4 and 6.3 AU (corresponding to slightly more than hard on the CR-10 scale). Importantly, RPE was significantly higher in semifinal games than group and round of 16 games. Interestingly, these results indicate a partial

Table 2 Results for the Dependent Variables According to Final Score Margin

	Balanced games	Unbalanced games	*P*	ES
HR_{mean}, %	85.5 ± 1.1	83.7 ± 1.9	.298	0.12, trivial
HR_{peak}, %	98.0 ± 0.5	96.9 ± 0.9	.178	0.33, small
RPE, AU	5.5 ± 0.3	4.7 ± 0.4	**.027**	0.49, small
Mental effort, AU	62.1 ± 3.4	52.5 ± 5.1	**.029**	0.50, small

Abbreviations: AU, arbitrary units; ES, effect size; HR_{mean}, mean heart rate; HR_{peak}, peak heart rate; RPE, rating of perceived exertion. Note: Variables are presented as estimated marginal mean ± SE. Note: Significant effects are represented in bold.

disagreement between internal load measures (HR and RPE). In fact, in 3×3 basketball[30] as well as in the classic 5×5 version,[31] the association between HR- and RPE-derived measures is typically moderate. Despite being both internal load measures, HR and RPE differ: while HR measures indicate the response of the athlete's physiological systems during exercise, perceived exertion reflects the conscious sensation of the effort a subject is exerting during a physical tasks[32] therefore belonging to the perceptual-cognitive domain. The RPE responses can indeed be influenced by technical–tactical constraints,[33] which are processed at the brain level when players interact with teammates and opponents, pay attention, and take decisions, as well as reflect psychoemotional responses, such as the higher demands of semifinal games compared with group games. In fact, our findings agree with 3 previous studies,[2,17,34] which also reported higher RPE scores in 3×3 knock-out stages compared to the group stage. Additionally, the higher RPE in semifinal games might be indicative of physical and/or mental fatigue accumulated by players after playing multiple games over the tournament phases.

In the current study, players reported higher RPE scores after lost games compared to won ones. It is unfortunately not possible to compare findings with previous studies about 3×3 basketball since this was not previously assessed. However, the increased perceived exertion registered following losses likely reflects the increased effort by players trying to recuperate the score margin during games in which their team is trailing. Regarding the final score margin, it is not surprising that balanced games had significantly higher RPE than unbalanced games. In these games, the competitiveness is heightened, with players likely exerting greater effort to lead the score or recuperate it. This hypothesis is supported by a previous 5×5 study[18] which found significantly higher external (ie, Playerload, accelerations, changes of direction) as well as internal (summated-heart-rate-zones load, RPE, session RPE) loads, which indicate how players increase their physical outputs during balanced games, which in turn, result in higher internal load responses, including RPE.

To our knowledge, this was the first study assessing the mental demands of 3×3 basketball, and the second study using the ME in basketball settings. Previously, Sansone et al[35] found values of ~45 AU during demanding 3×3 small-sided games played by adult males. Extending to other team sports, Badin et al[24] reported ME values of ~53 AU after soccer small-sided games. In the current study, significantly higher ME was found during the knock-out stage games (59–72 AU). In this sense, the setting of knock-out games significantly placed players under greater cognitive and emotional demands,[11,15] as reflected in the ME scores. These "win-or-go-home" games are naturally more mentally and emotionally demanding, with only one possible game outcome (winning) to be useful for the team to proceed in the tournament. Higher ME scores possibly also reflect the greater focus and heightened use of cognitive resources implemented by players to improve performance in such decisive games. As suggested by previous studies,[11,15] the heightened cognitive and emotional demands of such games likely determined the higher ME values found.

No effect of game outcome was found for ME. It appears that the cognitive effort and use of resources by players in our study was similar across won and loss games, which is indicative of the competitive, professional approach applied by players in the official tournament settings. In contrast, ME was significantly higher in balanced games compared to unbalanced games, aligning with the results observed for RPE. In tightly contested games, where the outcome remains uncertain, it is unsurprising that 3×3 players exerted greater cognitive effort compared to unbalanced games, where a larger score margin and reduced competitiveness likely led to lower gameplay intensity.[18] Taken together, these findings suggest that balanced 3×3 games impose greater perceptual and mental demands on players.

This study has some limitations in the absence of external (physical) load data, the limited number of tournaments monitored, and the specific sample investigated. Furthermore, the HR_{max} value was obtained from the games monitored, which might have led to an overestimation of physiological responses. Future studies should monitor the physical demands data across multiple tournaments, including other populations (female, elite players) and obtain peak HR values with maximal fitness testing (ie, 30-15 Intermittent Fitness Test, Yo-Yo Intermittent Recovery) for a more accurate quantification of physiological responses. In addition, while we measured subjective mental demands, future studies should consider measuring objective markers (ie, presence of mental fatigue using brain-derived functional measures), before, and after 3×3 tournaments.

Practical Applications

First, demanding drills should be designed to appropriately prepare 3×3 basketball players for the HR_{max} demands imposed, as these might negatively affect technical–tactical performance.[36]

Second, as 3×3 basketball games are perceived to be somewhat more than hard (RPE: 4.4–5.7), 3×3 training should encompass very hard and intense phases to make sure players can efficiently cope with such perceptual demands. Third, seen the increasing perceptual and mental demands placed by knock-out stage games, players should be placed in "win-or-go-home" situations, for instance by manipulating constraints in game-based conditioning or by participating to friendly tournaments to improve preparedness for the perceptual-cognitive demands of decisive knock-out stage games.

Similarly, as balanced games posit greater perceptual and mental demands, the score-line constraint can be manipulated by 3×3 coaches during game-based conditioning to place players

in scenarios where the game is more competitive, undecided, and intense.

Conclusions

Three-on-three basketball tournaments impose considerable cardiovascular, perceptual, and mental demands. While cardiovascular responses stay similar across tournament phases, perceptual and mental demands are higher in the knockout tournament phases, compared with group stage. Game outcome influenced only RPE scores, while balanced games posited greater perceptual and mental demands compared with unbalanced games, likely due to greater competitiveness and heightened psychoemotional demands.

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