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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

The influence of physical fitness qualities, individual characteristics and contextual factors on youth basketball players' perceived exertion and recovery responses to official games

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ABSTRACT

BACKGROUND: This study examined the influence of physical fitness qualities, individual characteristics, and contextual factors on perceived exertion and recovery responses to official games in youth basketball players.

METHODS: Twenty-six males (age: 15.8±1.2 years; 12 guards, 9 forwards, and 5 centers) and 7 females (age: 16.1±0.9 years; 3 guards, 4 forwards) were monitored for an entire basketball season (N.=635 observations). Yo-Yo Intermittent Recovery (level 1) and countermovement jump (CMJ) tests were administered, with players categorized as high and low Yo-Yo and CMJ groups according to test results. Ratings of perceived exertion (RPE) were collected after each official game. Before the game and the day after, the Total Quality of Recovery (scores) were collected, and the difference between post- and pregame TQR was calculated (TQRΔ). Separate linear mixed models evaluated the effects of sex (M; F), fitness qualities (high Yo-Yo; low Yo-Yo) (high CMJ; low CMJ), playing position (guard; forward; center), game outcome (won; loss) and game location (home; away).

RESULTS: Male players reported higher RPE (7.0±0.3) than females (5.5±0.4) (P=0.003, effect size [ES]: moderate). Players with high Yo-Yo performance also reported higher RPE (6.7±0.4) than low Yo-Yo (5.8±0.3) (P=0.049, ES: small). TQRΔ was higher in guards (-1.3±0.2) than forwards (-0.8±0.2) (P=0.041, ES: trivial), and lower after lost games (-0.8±0.2) compared to won games (-1.2±0.2) (P=0.002, ES: small).

CONCLUSIONS: In youth basketball, postgame perceived exertion and recovery responses are influenced by players' sex, intermittent endurance capacity, and game outcome. Current findings can help youth basketball practitioners to better understand their players' performances and perceptual responses.

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KEY WORDS: Team sports; Athletic performance; Youth sports.

In team sports, competitive performance is possibly the most important moment of the seasonal work of coaches and players. Success in competition is essential at both the individual (for career progress and athlete development) and the team level (to win trophies and improve financial returns and social recognition). By analyzing players' performance and their responses to competition,[1] team sport practitioners quantitatively and qualitatively[2] assess performance indicators, from which they can assume the progress made by players and the entire team across microcycles and mesocycles. Specifically for youth sports, performance and athlete monitoring are essential tools that serve

as an opportunity for players to get to know themselves, as athletes and performers, and develop a performance profile that can be used to strategize training plans for long-term athletic development.[3] Basketball is an intermittent-based, stochastic team sport[4] in which performance is determined by the complex, non-linear interactions[5] between physical, perceptual, individual, and contextual factors.[1, 6] The physical fitness qualities of basketball players are the base on which their physical performance is expressed during competition. Studies have shown[7, 8] that basketball players competing in higher-level leagues have better fitness capacities, including better intermittent endurance and neuromuscular power capacities, than players competing at lower levels. In fact, physical qualities are an important, discriminating aspect considered by basketball scouts when selecting players.[9] This is because high-level basketball performance is characterized by considerable physical and physiological demands, which progressively increase as the competition level is raised.[10, 11] Therefore, regularly monitoring the physical capacities of basketball players is necessary in order to understand the players' abilities to cope with training and competition demands.[7, 12] Thus, the physical fitness of team sport players has been shown to influence their performances during competition,[13, 14] as well as their postgame recovery profile.[15] Specifically for youth basketball, physical performances (*i.e.* external load outputs) in simulated matches were found to be higher in players with better neuromuscular and change of direction capacities.[13] These higher external loads performed during competition can lead to higher perceived exertion,[16] and also result in a delayed postmatch recovery response, compared to those of players with lower physical capacities, which have been shown to perform lower game loads[13, 14] and have a faster recovery profile.[15] This information is essential for performance staff to have plausible expectations of the players' performance in games and on their postmatch recovery strategies. Basketball performance has been also shown to be influenced by individual and contextual factors.[2, 17] Typically, basketball players are categorized according to their playing position. Guards are typically less tall, and have better speed and endurance capacities, with their technical-tactical tasks being characterized by setting the offense pace, deciding and calling set plays, and creating advantages on the perimeter.[8, 18] Forwards have a more hybrid profile, characterized by intermediate metabolic and power capacities, and technical-tactical tasks which require versatility both far and close to the basket. Centers, in contrast, typically play in the 3-seconds area, where they can capitalize on their superior size and strength by scoring 2-point shots, collecting rebounds, and blocking shots.[2, 17] Regarding contextual factors, game location has been widely recognized to influence team sports performance, including in basketball.[19] Further, game outcome (winning or losing) has been shown to influence players' postgame perceptual responses,[20, 21] likely due to the different socioemotional implications of the game result. In order to have a comprehensive understanding of basketball players' performances and their postgame responses, it might be beneficial to apply a multidisciplinary perspective that takes into account physical, perceptual, individual, and contextual aspects. This information would allow coaches and practitioners to better organize training and recovery schedules across the competitive season by having more detailed information, with the final aim of improving performance and health of their players. Therefore, this study aimed to evaluate perceived exertion and recovery responses in youth basketball players according to their physical fitness qualities, individual characteristics, and game-related contextual factors.

Materials and methods

Subjects

Twenty-six males (age: 15.8±1.2 years; height: 186.0±8.4 cm; body mass: 78.0±11.7 kg; playing position: 12 guards, 9 forwards, 5 centers; playing experience: 7.6±2.8 years) and 7 females (age: 16.1±0.9 years; height: 163.6±3.4 cm; body mass: 60.1±5.4 kg; playing position: 3 guards, 4 forwards; playing experience: 9.1±1.4 years) youth basketball players were recruited for this study. Before the start of data collection, each player and their parents/guardians were informed about the monitoring procedures, and one of their parents/guardians signed a consent form which complied with the ethical standards of the Declaration of Helsinki. Personal data was handled respecting anonymousness according to the European Data Protection Law.

Design

The study followed the recruited basketball players across an entire basketball season. Typically, the players participated to 3-4 team-based training sessions (80-120 minutes) and 1-3 individual physical training sessions (40-75 minutes) per week. Most commonly, 1 official game was played at the end of each week. Players underwent fitness testing at the end of the preseason, at the mid-point of the regular season, and after the end of the season. Perceived

exertion and recovery scores from official games were obtained for a total of 635 individual observations.

Procedures

Each team's coaching staff involved classified players in three playing position categories (guards; forwards; centers).[2] The following fitness tests were administered: 1) Yo-Yo Intermittent recovery (level 1),[22] to assess intermittent endurance capacity; and 2) countermovement jump (CMJ) test, to evaluate lower limb power. Briefly, the Yo-Yo test requires athletes to perform 20m+20m shuttle runs interspersed by 10 seconds of recovery at an increasing speed, until failure.[22] The distance covered (in meters) in the Yo-Yo test was registered. Regarding the CMJ (no arm swing), three trials were performed in each testing window, with the height (in cm) of the highest jump considered. CMJ height was measured using the previously validated[23] MyJump app (Carlos Balsalobre-Fernández, Madrid, Spain). One hour before and one day after each official game, players reported their perception of recovery using a modified 10-point Total Quality of Recovery (TQR) Scale, which has been previously implemented in basketball research.[2, 24] According to Kentta *et al.*, players were instructed to pay attention to psychophysical cues[25, 26] of recovery (*e.g.*, mood states, soreness, heaviness) when reporting their TQR scores. The score collected before the game was subtracted from the score collected after the game (*e.g.*, TQR pregame: 7; TQR postgame: 5, = -2) to evaluate the decrement in perceived recovery. This score was labeled TQRΔ. Between 10 and 30 minutes after the end of each basketball game, players reported their rating of perceived exertion (RPE) using the CR-10 scale.[27] This method has been previously validated and used in basketball settings,[27, 28] including with youth athletes.[18, 29] Game-related contextual factors were also monitored, specifically, the game location (home; away), and game outcome (won; lost) seeing their previously demonstrated influences on players' performances and perceptual responses.[1, 21, 30]

Statistical analysis

Statistical analyses were performed with Jamovi (version 2.3; www.jamovi.org) with the α level set at 0.05. Following previous studies,[14, 15] a median split was used to classify players into high- and low-fitness groups (high Yo-Yo and low Yo-Yo; high CMJ and low CMJ) based on their fitness test results. Separate linear mixed models were performed to examine the effects of sex (M; F), fitness level (high; low), playing position (guard; forward; center), game location (home; away), and game outcome (won; loss) on RPE and TQRΔ. Players were inserted as random effects in the models to account for repeated measures. For RPE, playing time was inserted as a covariate in the model to control for its influence.[1, 31] Data distribution and outliers were inspected before running the analyses. For each model, Akaike's Information Criterion (AIC), F and P values, and estimated marginal means (EMM) ± standard error (SE) were computed. *Post-hoc* comparisons were performed using Bonferroni, with effect sizes calculated as Cohen's *d* and interpreted as:[32] <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.

Results

Table I presents the fitness test results for male and female players. Regarding RPE (AIC: 1700.37), main effects were found for sex (F=11.31664, P=0.003) and Yo-Yo (AIC) (F=4.34735, P=0.048), while no effects were found for CMJ, playing position, game location or game outcome (all P>0.05). For TQRΔ (AIC: 1679.49), main effects were registered for playing position (F=3.647, P=0.043) and game outcome (F=9.546, P=0.002), while no effects were found for sex, Yo-Yo, CMJ or game location (all P>0.05). Table II, III present the results for the significantly different *post-hoc* comparisons for RPE and TQRΔ, respectively.

Discussion

This study aimed at examining the effects of physical capacities, individual and contextual factors on perceived exertion and recovery responses of youth basketball players in official competition settings. The main findings of

TABLE I.—*Fitness test results according to player sex.*

	M	F
Yo-Yo (m)	1080±366	720±228
CMJ (cm)	40.1±5.9	24.4±10.4

CMJ: countermovement jump; F: females; M: males.

TABLE II.—*Significant* post-hoc *comparisons for RPE.*

Variables	RPE	P value and ES
Sex		
M	7.0±0.3	P=0.003, ES: 0.97, moderate
F	5.5±0.4	
Yo-Yo		
High	6.7±0.4	P=0.049, ES: 0.48, small
Low	5.8±0.3	

ES: effect size; F: females; M: males; RPE: rating of perceived exertion.

TABLE III.—*Significant* post-hoc *comparisons for TQRΔ.*

Variables	TQRΔ	P value and ES
Playing position		
Guard	1.3±0.2	Higher in guards than forwards,
Forward	-0.8±0.2	P=0.041, ES: 0.13, trivial
Center	-1.0±0.4	
Game outcome		
Won	-1.2±0.2	P=0.002, ES: 0.23, *small*
Lost	-0.8±0.2	

ES: effect size; TQRΔ: total quality of recovery delta.

this study were: 1) the sex differences in RPE (higher in males than females); 2) the higher internal loads reported by players with better intermittent endurance capacity; 3) the contextual effect of the game outcome on postgame recovery, likely due to the socioemotional consequences of winning or losing the game; 4) no effects were found due to playing position, CMJ capacity nor game location. In this study, male players reported higher RPE scores than females. Our findings agree with recent research,[33] which also found higher RPE scores in young males in correspondence of also greater physical work outputs. In youth basketball, the court area and the rules are the same in both male and female competition, despite the lower absolute physical capacities of female athletes compared to males,[34] especially for intermittent endurance, sprinting, and changes of direction. While we did not directly measure external load, it is possible that the male players performed more physical work on the court (*i.e.* covered higher distances, more jumps, and sprints) than females, which in turn led to higher internal loads, expressed in the higher RPE scores obtained. Regarding physical capacities, players with better Yo-Yo performance reported higher game RPE scores. Better endurance capacity has been associated with better game performance and higher physical outputs in various team sports,[15, 35] since it allows players to perform more on-court actions and recover more effectively in between repeated high-intensity efforts.[22, 36] While we did not directly monitor physical outputs (*i.e.* external load), players with better Yo-Yo results in this study likely performed more total work during games, which in turn determines greater internal responses (higher RPE).[16] Differently, no effects of CMJ test results were found for RPE or TQRΔ. In particular, the CMJ test is a single, maximal action requiring mostly muscle power. While basketball game-play is characterized by frequent jumps,[4] the limiting factors for basketball performance are mostly related to the metabolic and fatigue-resistance domains, such as intermittent endurance, buffer capacity, and repeated sprint ability,[4, 36] which allow players to cope with the game demands and the fatigue that accumulates due to the multiple intense actions performed during game-play. We did not find substantial differences in RPE or TQRΔ between playing positions. Our findings agree with a previous study in elite male basketball, which did not find significant differences in perceived training loads between guards, forwards, and centers.[37] At the youth level, the playing positions may be less defined and more fluid. To promote motor learning, it is beneficial for youth sports coaches to increase training variability by assigning players to multiple different tasks,[5, 6] and not only those of their playing positions. This, in turn, could lead to less differentiated performance profiles, which would lead to similar postgame exertion and recovery responses. Regarding contextual factors, greater decrements in TQR scores were found after won games, compared to lost games. Previous studies in team sports have identified the influence of game outcomes on the perceptual responses of players.[20, 38] When reporting perceptual scores, socioemotional factors come into play. Noticeably, recent evidence suggests that players might modify or lie about their athlete-reported outcome measures for their performance not to be questioned,[39] which is what might have happened in this study after lost games, with players attenuating their recovery scores. In contrast, no effects for game location were found, which agrees with previous basketball studies showing similar game performances and physical demands in games played at home or away.[1, 21]

Limitations of the study

This study carries some limitations in the lack of objective measures of physical performance (*i.e.*, external load) and physiological responses to games (*i.e.*, heart rate variability, muscle fatigue). Future studies should monitor these variables alongside perceived exertion and recovery responses to official games in order to better quantify the dose-response relationship between the external load and the internal players' response, which can be used when manipulating playing times during games and overall training loads.

Conclusions

In youth basketball, postgame perceived exertion and recovery responses are influenced by players' sex, intermittent endurance capacity, and game outcome. Male players reported higher RPE scores than females. Players with better Yo-Yo test results accumulated higher internal loads, possibly due to greater physical outputs. These higher in-

ternal loads should be considered by coaches when managing postgame recovery strategies and weekly training plans, in order to optimally maintain player performance and health. After lost games, lower decrements of recovery scores were found, with a potential influence of socio-emotional expectations associated with athlete-reported outcome measures. Therefore, basketball performance staff should consider the confounding effects of game outcomes on perceived recovery indicators. Altogether, youth basketball performance staff should consider this information to better understand their players' performances and perceptual responses.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

Pierpaolo Sansone, Lorenzo Gasperi and Antonio Tessitore have given substantial contributions to the study conception and design; Pierpaolo Sansone, Lorenzo Gasperi and Miguel Gomez-Ruano contributed to the acquisition, analysis, and interpretation; all authors have participated to the manuscript draft, Pierpaolo Sansone revised it critically. All authors read and approved the final version of the manuscript.

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