

3 × 3 Basketball: Neuromuscular Fatigue Develops While External Intensities Are Maintained in Late Tournament Stages

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Purpose: To evaluate physical demands and acute neuromuscular responses in official 3 × 3 basketball tournaments. **Methods:** Thirty-three male players (age: 23.1 [5.6] y) were monitored during 2 tournaments, featuring 3 group games (GG1, GG2, and GG3) on day 1 and the round of 16 (R16), quarterfinal (QF), semifinal (SF), and final games on day 2. External intensity (movement intensity) was measured using microsensors. Bilateral countermovement-jump testing was conducted before the start of the tournaments and immediately after each game using MyJump Lab to measure jump height, time to takeoff (TTTO), and modified Reactive Strength Index (RSI_{mod}). **Results:** Linear mixed models revealed no significant differences for movement intensity ($P = .195$) but a practically meaningful decrease (>smallest worthwhile change [SWC]) in the QF compared with GG1, GG2, GG3, R16, and SF. No significant ($P = .128$) or practically meaningful differences were found for jump height. TTTO was shorter following GG3 compared with baseline ($P = .027$, effect size: *moderate*). Practically meaningful (>SWC) decreases in TTTO were found from baseline to post-GG1, GG2, and GG3, while TTTO increased on day 2 compared with day 1 and after SF and Final compared with R16 and QF. RSI_{mod} significantly (all $P < .05$) and practically improved (>SWC) from baseline to post-GG1, GG2, and GG3 (effect size: *trivial*); practically meaningful changes were also identified on day 2, with poorer RSI_{mod} following QF compared with all day 1 games and poorer values post-SF compared with post-GG3. **Conclusions:** While players maintained in-game physical intensities across tournament stages, neuromuscular status worsened on day 2, suggesting the presence of fatigue. Strategies aimed at supporting players' physical performances in late 3 × 3 tournament stages should be identified.

Keywords: 3 vs 3, 3 × 3 basketball, team sport, external load, CMJ

3 × 3 basketball is a modified version of the traditional 5-vs-5 format, one of the most widely played sports worldwide. Often referred to as "street basketball," this variation has long been embraced by players across all competitive levels, from amateur to elite. Its global appeal stems from its accessibility and simplicity, requiring just a hoop and a ball. Recognizing its popularity, the International Basketball Federation (FIBA) formalized the sport by establishing official rules and organizing the first 3 × 3 World Cup in 2010. In recent years, the sport has gained significant momentum achieving a milestone with its inclusion in the Tokyo 2020 Olympics and continuing in the Paris 2024 and Los Angeles 2028 Olympics. This growing importance has sparked interest from coaches and researchers seeking to understand 3 × 3 basketball's unique performance demands which are crucial for developing effective training methods, competition, and player selection processes.

The physical and physiological demands of 3 × 3 basketball have been extensively studied,¹⁻³ with a recent systematic review⁴ providing a detailed performance profile of the sport. 3 × 3 games last 10 to 15 minutes and are characterized by a highly intermittent nature (1:1 work–rest ratio), with brief ball possessions (6–8 s), and significant physical demands, including


17 to 33 accelerations, 24 to 44 decelerations, 62 to 94 changes of direction, and 17 to 24 jumps per game.⁴ Compared with traditional 5 × 5 basketball, 3 × 3 involves a greater proportion of high-intensity activity (~24% vs ~9% of live time) and moderate-intensity activity (~17% vs ~10%), along with considerably less recovery time during games (~15% vs ~36%).^{3,5} These findings underscore the unique intensity and limited recovery periods in 3 × 3 basketball, highlighting its distinction as a separate sport from 5vs5 basketball.

Key characteristic of 3 × 3 basketball tournaments is their structure, consisting of a group stage, followed by a knockout phase, typically held over a compact duration of 2 to 7 days, with players required to compete in multiple games per day.⁶ Research on the physical demands across tournament phases in male 3 × 3 basketball has produced conflicting results.^{1,7} For instance, Ferioli et al⁷ observed a reduction in high-intensity activity and an increase in recovery time during the knockout phase. Conversely, Montgomery and Maloney¹ reported greater distances covered and more high-intensity changes of direction in final games. As of now, it remains unclear how physical demands evolve over the course of a tournament for male players. Previous research on 3 × 3 basketball has primarily focused on null hypothesis testing, neglecting the assessment of "real" performance changes, such as the smallest worthwhile change (SWC).^{8,9} The SWC is a practically significant measure that can guide coaching and medical decisions. Understanding whether the physical demands and performance of 3 × 3 players vary across competition phases could have important implications for tactical and strategic planning, as well as for selecting appropriate recovery strategies.

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Given the repeated competitive efforts required in 3×3 basketball tournaments—up to 18 games over 5 days⁷—players are likely to accumulate fatigue as the tournament progresses. Fatigue has been defined as “an inability to complete a task that was once achievable within a recent time frame”¹⁰ and can be detected at the physiological (ie, hormonal disruptions, muscle damage), perceptual-cognitive (ie, decision making, stress, mood), and objective performance (ie, neuromuscular output) levels.¹¹ This fatigue can impair players’ physical and technical-tactical performance during competition, ultimately reducing their team’s likelihood of success. A particularly relevant area for 3×3 research is neuromuscular fatigue, which may be caused by repeated stretch-shortening cycle actions, given the sport’s high external loads—such as frequent accelerations, jumps, and changes of direction—that place significant demands on the neuromuscular system.⁴ Surprisingly, no study to date has directly monitored players’ neuromuscular responses across the games and stages of 3×3 tournaments, representing a significant gap in the current body of knowledge.

Therefore, this study aims to assess the physical demands and acute neuromuscular responses of male 3×3 basketball players throughout a tournament. Specifically, it seeks to (1) profile the physical demands across different games and tournament phases, (2) evaluate whether 3×3 games induce acute changes in neuromuscular outputs and whether fatigue accumulates over the tournament, and (3) examine the relationship between physical demands and acute neuromuscular responses.

Methods

Subjects

Thirty-three adult male basketball players (mean [SD]: age: 23.1 [5.6] y, height: 191.4 [11.2] cm, body mass: 86.8 [10.3] kg) volunteered to participate in this study. The recruited players primarily competed in 5vs5 basketball leagues, ranging from regional to national levels (tiers 2–3).¹² Data from players who sustained injuries or fell ill during the tournament were excluded, resulting in a total of 151 individual observations ($n = 2.9 [1.1]$ per player). Prior to the study, all players were informed about the monitoring procedures and provided written informed consent. The research project was approved by the Institutional Review Board of the University of Rome “Foro Italico” (approval number: CAR 208/2024).

Study Design

This descriptive, longitudinal study monitored players across 2 official 3×3 basketball tournaments organized by the Italian Basketball Federation. The tournaments spanned 2 days: the first day was dedicated to group stage games (each team played 3 games—group game 1 [GG1], group game 2 [GG2], and group game 3 [GG3]), while the second day was reserved for elimination rounds, including the round of 16 (R16), quarterfinals (QF), semifinals (SF), and final (F) for teams that advanced. On both days, games were interspersed with ~30 minutes of rest.

According to the official 3×3 basketball rules established by FIBA, teams consisted of 3 to 4 players, with unlimited substitutions possible; games were played on a 15×11-m court with a single hoop, lasting 10 minutes, or concluding earlier if a team scored 21 points. Teams were required to attempt a shot within 12 seconds of gaining possession. The scoring system awarded 1

point for successful shots inside the arc or from free throws, and 2 points for shots made from beyond the arc. All games were played outdoors, with an average temperature of 26.0 °C and a humidity level of 53.6%.

Monitoring of Physical Demands

Physical demand data were collected using a 50-Hz triaxial accelerometer (Firstbeat), firmly affixed to the players’ chest (at the base of the sternum) via textile straps. The physical demands were measured (in arbitrary units) using the variable movement intensity (MI). MI is calculated by dividing the sum of accelerations performed by athletes across the 3 movement axes by the duration in minutes of the exercise session (ie, game, including all breaks and substitution), therefore representing the external intensity performed by the athlete. This variable has been previously used with success to monitor physical demands in basketball settings.¹³

Fatigue Monitoring: Acute Neuromuscular Responses

Acute neuromuscular responses were assessed using a bilateral countermovement jump (CMJ) without arm swing. CMJ testing has been widely used in team sports as it involves the stretch-shortening cycle,^{14,15} making it particularly relevant for 3×3 basketball. This method provides quick, valid, and reliable insights into the athlete’s neuromuscular status.¹⁶ Each day, CMJ performance was registered (1) before the start of the competitions and (2) immediately after each game. Before the baseline CMJ trial (before the start of the competition), players completed an 8-minute standardized warm-up including jogging, dynamic stretching, lower limb exercises (ie, squats, lunges), plyometrics, and 3 submaximal-to-maximal trials of the CMJ motion. Postgame CMJ was assessed without following this warm-up procedure, with a brief recovery of <2 minutes given to players to rehydrate and recover.

CMJs were performed as follows^{17,18}: players started in the standing position, with the lower limbs fully extended, feet placed at a comfortable width, and hands on the hips; subjects started the countermovement motion up to a self-selected depth, followed by a maximal vertical jump. In all instances, players were asked to perform their best effort possible and to try jumping the highest they could. Two trials, interspersed by 1-minute rest,^{17,18} were registered for each time-point collection to reduce measurement error. To reduce the potential confounding effect of learning between players with different CMJ testing experiences, the best performance value among the 2 trials was retained for analyses.¹⁹ If the CMJ motion was not performed correctly (ie, hands off the hips, tucking/flexing the legs in the flying phase), the jump was repeated after 1 minute.

CMJs were analyzed using the MyJump Lab smartphone application, which has been validated as a reliable tool for assessing CMJ metrics.^{17,18,20} CMJ trials were recorded (at 240 fps) using an Apple iPhone 12, with the camera placed so that the full frame of players was captured throughout the ground contact phase of the jump. An experienced sport scientist with >5 years’ experience and proficiency with the MyJump Lab application analyzed videos to obtain^{16,17}: (1) jump height (JH; vertical displacement of the athlete’s center of mass, in centimeters), (2) time to takeoff (TTTO; the time between the initiation of the countermovement to the moment of take off; in seconds), and (3) modified Reactive Strength Index (RSI_{mod} ; ratio between JH and time to produce the output, ie, TTTO; in arbitrary units). These variables were chosen as JH represents the performance proxy measure, while TTTO and

RSI_{mod} express changes in the neuromuscular strategy of athletes which are indicative of neuromuscular fatigue.¹⁶ Higher JH represents a better overall performance, while shorter TTTO alongside maintained JH and higher RSI_{mod} indicate better neuromuscular status.¹⁶ The JH, TTTO, and RSI_{mod} values obtained using MyJump Lab have been shown to be highly accurate, comparable to those measured with gold-standard instruments (eg, 1000-Hz force plates), and demonstrate good to excellent reliability (intraclass correlation coefficient: .79–.94).^{17,21} Following previous research,^{10,16} neuromuscular fatigue was identified as (1) an increase in TTTO with no concurrent increase in JH compared with a previous time point and/or (2) a reduction in RSI_{mod} compared with a previous time point.

Statistical Analyses

Data were analyzed using *Jamovi* statistical software (version 2.3) and customized Excel spreadsheets, with α value set at .05. Separate linear mixed models were performed to evaluate physical demands (MI) and CMJ variables (JH, TTTO, and RSI_{mod}) across the different tournament phases. Specifically, the game (7 levels: GG1, GG2, GG3, R16, QF, SF, and F) was set as fixed effect, whereas individual players were inserted as random effects to account for repeated measures. Post hoc Bonferroni correction was applied to identify changes between games for all variables. Akaike's Information Criterion (AIC), F , P values, and estimated marginal means (EMM; mean \pm SE) are reported for all models. For pairwise comparisons, effect sizes (ESs) were calculated as r (ES correlations) by converting the t statistics derived from the mixed models²² and interpreted as: $r \leq .1$ (*trivial*), $.1$ to $.3$ (*small*), $.3$ to $.5$ (*moderate*), $.5$ to $.7$ (*large*), $.7$ to $.9$ (*very large*), and $\geq .9$ (*almost perfect*).

The SWC was calculated to identify practically significant changes in physical demands and CMJ variables.^{8,9} The SWC for each variable was calculated by multiplying the group SD in each variable and multiplying it by 0.6, considering the heterogeneity in the participants' fitness levels.²³ The SWC value was then compared to the absolute difference in pairwise comparisons obtained from the mixed models to identify practically meaningful changes ($>SWC$) in physical demands and acute neuromuscular responses across tournament phases.

The associations between physical demands (ie, MI) and changes in acute neuromuscular responses were evaluated using repeated-measures correlation analyses,²⁴ as previously adopted in basketball research^{13,25,26} with nonindependent data (ie, multiple time points for the same individual). Repeated-measures correlations were computed between absolute MI values and the changes in JH, TTTO, and RSI_{mod} between baseline (ie, before the start of the daily games) and postgame responses, by calculating the difference between postgame CMJ results and the pregame values. Correlation coefficients (r) are presented with 95% CIs and P values and interpreted as previously mentioned.

Results

Table 1 presents the descriptive statistics and SWCs for MI and CMJ variables.

Physical Demands

Figure 1 shows the MI results across tournament phases. The mixed model showed no statistically significant differences in physical demands (AIC: 225.739) between games ($F = 1.50$, $P = .195$). All

Table 1 Descriptive Data and SWC Thresholds

Variable	Mean (SD)	SWC
Movement intensity, AU	4.0 (0.9)	0.52
Jump height, cm	36.9 (8.5)	5.1
Time to takeoff, ms	818.0 (100.0)	100.1
RSI_{mod} , AU	0.46 (0.12)	0.07

Abbreviations: AU, arbitrary units; RSI_{mod} , modified Reactive Strength Index; SWC, smallest worthwhile change.

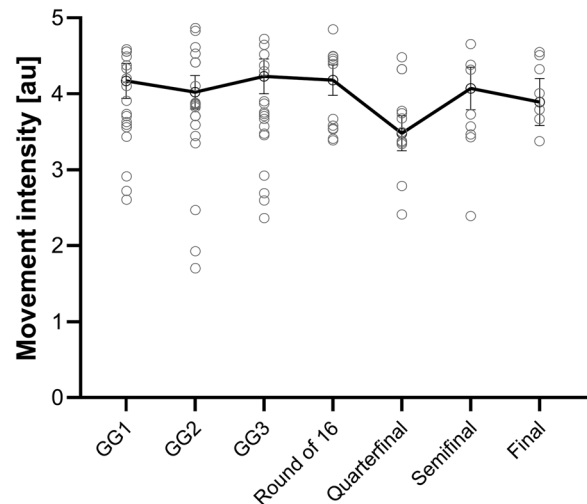


Figure 1 — Movement intensity across tournament phases. AU indicates arbitrary units; GG1, game 1; GG2, game 2; GG3, game 3.

comparisons had trivial ES differences, except a *small* difference (ES: .10) in MI between R16 and F (higher in R16).

Acute Neuromuscular Responses

Figure 2 shows the results for JH, TTTO, and RSI_{mod} across tournament phases. For JH (AIC: 957.716), no statistically significant differences were found between games ($F = 1.65$, $P = 0.128$). Considering the ES, the following differences were identified: higher JH post-GG1, GG2, GG3, and F compared with baseline (ESs: .11–.30, *small-moderate*); higher JH post-GG2 and GG3 compared with post-R16 and post-QF (ESs: .13–.17, *small*); and higher JH post-F than post-R16 and QF (ESs: .10–.11, *small*).

For TTTO (AIC: 1929.515), the mixed model showed a significant effect of tournament phase ($F = 3.19$, $P = .004$). Post hoc comparisons identified only one statistically significant difference in TTTO, which was shorter post-GG3 compared with baseline ($P = .027$). Considering ES differences, baseline jumps had longer TTTO than post-GG1 (ES: .20, *small*), GG2 (ES: .26, *small*), GG3 (ES: .30, *moderate*), and R16 (ES: .16, *small*), and shorter TTTO than post-SF (ES: .11, *small*); TTTO post-GG1 and post-GG3 were shorter than post-R16, QF, SF, and F (ESs: .11–.27, *small*); TTTO post-GG2 was shorter than post-SF and F (ESs: .16–.21, *small*); and TTTO post-R16 and QF were shorter than post-SF and F (ESs: .12–.19, *small*).

For RSI_{mod} (AIC: –286.622), the mixed model showed a significant effect of tournament phase ($F = 4.38$, $P < .001$). Post

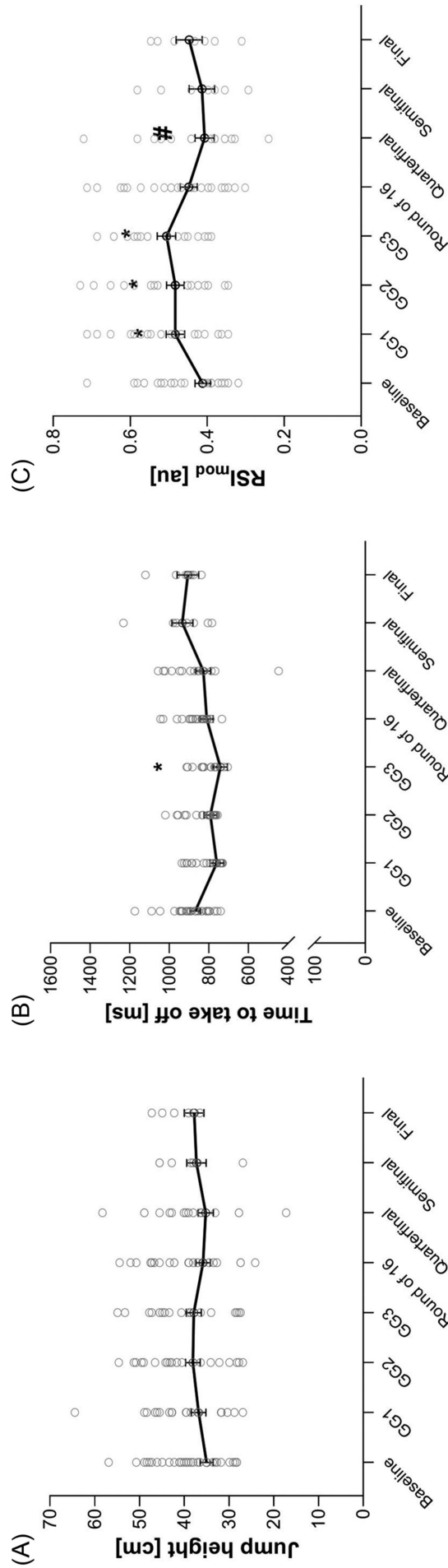


Figure 2 — Countermovement-jump variables across tournament phases. (A) Jump height, (B) time to takeoff, and (C) RSI_{mod}. AU indicates arbitrary units; GG1, game 1; GG2, game 2; GG3, game 3; RSI_{mod}, modified Reactive Strength Index. *Significantly different than baseline, #Significantly different than GG3.

hoc comparisons identified statistically significant lower RSI_{mod} at baseline compared with post-GG1 ($P = .023$), post-GG2 ($P = .014$), and post-GG3 ($P < .001$), and higher post-GG3 than post-QF ($P = .013$); however, all comparisons held only *trivial* ESs.

Repeated-measures correlation analyses showed small, non-significant associations between MI and JH changes ($r = -.10$; 95% CI, $-.372$ to $.192$, $P = .508$, *small*), TTTO changes ($r = -.11$; 95% CI, $-.381$ to $.181$, $P = .461$, *small*), and RSI_{mod} changes ($r = -.12$; 95% CI, $-.387$ to $.174$, $P = .433$, *small*).

Practically Meaningful Results (SWC)

When applying the SWC criteria to games comparisons, QF games had lower MI values compared with GG1, GG2, GG3, R16, and SF, while no other comparison held practical significance.

For JH, no comparison held practical significance.

The following TTTO results had practical significance (difference > SWC): TTTO decreased from baseline to post-GG1 and post-GG3; post-GG1, post-GG2, and post-GG3 TTTO were significantly lower than post-SF and post-F; and post-SF TTTO was significantly higher than post-R16 and post-QF.

RSI_{mod} meaningfully (difference > SWC) increased from baseline to post-GG1, post-GG2, and post-GG3; post-QF RSI_{mod} was meaningfully lower than post-GG1, post-GG2, and post-G3; and RSI_{mod} was meaningfully higher post-GG3 compared with post-SF.

Discussion

This study assessed the physical demands and acute neuromuscular responses of male 3×3 basketball players throughout a 2-day tournament, aiming to profile the physical demands across different tournament phases, evaluating the possible presence of neuromuscular fatigue, and examining the relationship between physical demands and acute neuromuscular responses. The main findings of this study were (1) physical demands were practically meaningfully lower in QF, which was associated with a concomitant reduction in RSI_{mod} compared with day 1 values, indicating the presence of neuromuscular fatigue; (2) compared with baseline, TTTO and RSI_{mod} improved in the first day of tournament after each of the 3 games, indicating the beneficial short-term effect of 3×3 gameplay on acute neuromuscular responses; and (3) neuromuscular fatigue was present in the second day of tournament, seen the worse values in TTTO and RSI_{mod} compared with day 1, with increasingly poorer status as the tournament progressed.

External intensities did not change across the tournament stages, except for a meaningfully lower MI found in QFs. These results partially align with previous 3×3 research using proxy variables (eg, PlayerLoad per minute), which found that physical demands were consistent across the stages of elite international 3×3 basketball tournaments.^{1,2} However, MI was meaningfully lower in the QF compared with most other phases, which should be considered by coaches and practitioners. Furthermore, considering MI data alongside acute neuromuscular responses, it is quite interesting that both MI and RSI_{mod} were meaningfully lower after the QF game compared with day 1 (post-GG1, GG2, and GG3). Thus, after accumulating a workload of 4 games, 3×3 players expressed lower physical intensities during the fifth game (ie, QF) which were accompanied with the presence of neuromuscular fatigue. Unfortunately, it is not possible to compare our findings since previous research did not monitor physical demands and neuromuscular responses of 3×3 players across multiple tournament games. One attempt was done by Cabarkapa et al²⁷ who evaluated CMJ responses in male national-

level athletes after 2 friendly 3×3 games, which however do not reflect neither the real external load volume (characterized by more games), nor the real psychophysiological stress imposed by the official 3×3 tournament settings.²⁸ Furthermore, practitioners should consider the fact that neuromuscular fatigue seems to reveal in later stages: specifically, RSI_{mod} was lower post-SF compared with post-GG3, alongside meaningfully lower TTTO post-SF than R16 and QF, and post-SF and post-F compared with the first day of tournament. However, this seemed not to affect players' external intensities during games, as shown by MI data. Altogether, these findings suggest that while 3×3 male players' neuromuscular status worsens in the second day of tournament and especially in later games, these reductions do not affect their physical intensity during games, except for a decrease in QF. The fact that MI was not decreased in SF and F (ie, later than the QF) hints at the possible role played by motivation under the specific contextual factors. That is, players in this study were able to (physically) perform at the same level of the first day during SF and F games, despite neuromuscular fatigue was present, possibly because of the prominent importance of these games for the tournament outcome. Indeed, it is not uncommon for basketball players to train and compete while displaying neuromuscular fatigue symptoms,²⁹ with prominent authors and practitioners suggesting that players' availability is the primary goal for the performance staff, rather than peak readiness conditions.³⁰

Practically meaningful increases of TTTO and RSI_{mod} were found from baseline to post-GG1, with even greater improvements registered post-GG2 and GG3. These findings suggest that 3×3 gameplay exerted positive effects on players' neuromuscular statuses, possibly indicative of warm-up and postactivation performance enhancement benefits. Exercise strategies resembling competition demands are key components of warm-up, increasing team sports athletes' subsequent performances.³¹ Furthermore, fast actions involving the stretch-shortening cycle (eg, jumps, changes of direction or reacceleration) have been shown to induce postactivation performance enhancement.^{32,33} Both aspects were likely present during the 3×3 games in this study, thus leading to the neuromuscular increases detected. Going into details, JH changes in day 1 did not hold practical significance (ie, <SWC), while jump strategy changes (TTTO and RSI_{mod}) did. Therefore, players displayed similar jump performances (ie, JH) while needing less time (ie, reduced TTTO) to produce the same output (JH). This scenario can be interpreted as an improvement in athletes' neuromuscular status as it infers improved ballistic qualities (ie, rate of force development).³⁴ The improved RSI_{mod} in day 1 is, logically, a product of the explained mechanism seen that RSI_{mod} is calculated from JH and TTTO; indeed, higher RSI_{mod} values indicate better neuromuscular status.³⁴ These increases might have been facilitated by the specific settings of the tournament, where athletes played 10-minute games which were interspersed by ~30 minutes of rest. This work:rest ratio (1:3) possibly favored a positive fitness-fatigue balance, with athletes improving their efficiency in the CMJ task.

Looking at CMJ responses in the second day, statistically significant and practically meaningful decreases from day 1 to day 2 were found for all variables, indicating the occurrence of neuromuscular fatigue. Noticeably, small decreases in JH were found from post-GG2 and GG3 to R16 and QF; most TTTO values registered in day 1 were shorter than the post-SF and post-F ones, alongside no changes in JH, thus showing better neuromuscular efficiency in day 1; additionally, RSI_{mod} post-QF and post-SF was worse than after group games. As TTTO and RSI_{mod} are sensitive in detecting acute neuromuscular fatigue,¹⁶ our findings demonstrate the occurrence of neuromuscular fatigue in 3×3 basketball players after competing in 4 games across 2 consecutive days. Seeing that the external

intensities (ie, MI data) were substantially similar across the 2 days, the identified fatigue cannot be attributed to the game intensity, but to the cumulative physical workload induced by playing multiple games. Results from the correlation analyses confirm this hypothesis, with only small, nonsignificant relationships between individual game physical demands and postgame CMJ variables changes.

This study has some limitations related to the sample investigated, the variables assessed, and the descriptive nature. Future 3×3 research should (1) involve female and elite-level players, who might express different neuromuscular responses according to their fitness level; (2) control and/or manipulate the activity between games by comparing passive rest against different strategies (re-warm-up and small-sided games) and see whether the external intensities and neuromuscular statuses are affected; (3) use ergogenic and nutritional strategies to favor players' recovery and performance; (4) evaluate the physical demands and neuromuscular responses in tournaments with different schedules; (5) monitor players' perceptual responses as well as their playing time; (6) evaluate tactical and contextual factors such as possession duration and score-line margin, as they might influence external intensities; and (7) evaluate if teams which advance in the tournament express different external intensities compared with nonqualified teams.

Practical Applications

As cumulative 3×3 gameplay induces neuromuscular fatigue after accumulating 4 to 5 games, it is necessary to identify counteracting strategies. Static stretching should be avoided, as it might decrease neuromuscular activation.³⁵ Ergogenic and nutritional strategies might also be implemented to counteract cumulative fatigue across 3×3 tournaments. Caffeine has been shown to improve performance markers of basketball players^{36,37} and counteract the effects of cumulative fatigue.^{38,39} Additionally, carbohydrate mouth rinsing might improve physical performances and technical skills while reducing perception of effort.⁴⁰

Conclusions

The physical demands of 3×3 male basketball tournaments are similar across different tournament stages, with a meaningful decrease present only at the fifth game (quarterfinal) played. On the first day of tournament, players' neuromuscular status benefits from gameplay, with improved markers of efficiency. Differently, on the second day of tournament, neuromuscular fatigue was detected, in the form of longer time to takeoff alongside similar jump height and reduced RSI_{mod}, especially in the later tournament phases. Current findings should be considered by male 3×3 basketball practitioners when involved in tournaments with similar schedules (ie, 2–3 games per day on consecutive days).

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