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Recovery kinetics of countermovement jump performance after soccer matches: differences between starters and non-starters

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Abstract: The present study aimed to explore differences in the recovery kinetics of countermovement jump performance in starting and non-starting soccer players after the competition. Twelve male outfield players (age: 27.05 ± 4.31 years; height: 177.50 ± 4.56 cm; body mass: 71.48 ± 4.63 kg) were included in this case series study. It included two data collection periods within a single competitive season, each encompassing one official match and the subsequent 48-h recovery period. Each participant was included in the starting line-up only in one match. Countermovement jump performance was monitored on each morning of the match-day, and subsequent measurements were acquired immediately post-, at 24-h and at 48-h post-match. Both output-orientated and time-based metrics were obtained from each jump. Afterwards, each participant's data was compared between two conditions: when they were a starter (included in the starting line-up) and when they were a non-starter (not included in the starting line-up, regardless of match playing time). Time-related changes in performance within each group were determined using a repeated-measures ANOVA with Holm post hoc analysis and the Cohen's d effect size statistic. Group differences in performance at post-match, 24-h, and 48-h post-match were determined by conducting ANCOVA with Holm post hoc analysis and partial eta squared, using pre-match values as covariates. Compared to baseline, jump height and propulsive impulse were significantly decreased at 24-h post-match only in starters ($p < 0.001$), while no significant time-related changes were found in non-starters. Compared to non-starters, starters exhibited a longer propulsive phase duration post-match ($p = 0.037$), lower jump height and propulsive impulse at 24-h post-match ($p = 0.019$, $p = 0.005$, respectively), and lower absolute peak power at 48-h post-match ($p = 0.042$). Thus, both jump outcome and movement strategy responses to neuromuscular fatigue evidenced a faster recovery of countermovement jump performance in non-starters players.

Keywords: fatigue, football, jump, performance, recovery

1. Introduction

Muscle fatigue is an exercise-induced reduction in maximal voluntary muscle force and can be attributed to both impaired muscle function and a decreased capacity of the central nervous system to activate muscles (Carroll, Taylor, & Gandevia, 2017; Gandevia, 2001). Traditionally, research on neuromuscular fatigue has employed isolated forms of muscle action (i.e., isometric, concentric, or eccentric) (Gandevia, 2001). However, the analysis of movements involving the stretch-shortening cycle (SSC) permits a more comprehensive investigation of neuromuscular fatigue because it includes metabolic, mechanical, and neural components of fatigue with impaired yawn reflex activation (Nicol, Avela, & Komi, 2006).

A common test that can yield valuable insight into an athlete´s neuromuscular and SSC capabilities is the countermovement jump (CMJ) test (Gathercole, Sporer, Stellingwerff, & Sleivert, 2015; McMahon, Suchomel, Lake, & Comfort, 2018), which has gained acceptance in sporting environments. Traditionally, CMJ performance has been quantified through jump height (Claudino et al., 2017). However, this metric may exhibit lower sensitivity compared to other time-based metrics in detecting the onset of neuromuscular fatigue (Franceschi et al., 2023; Gathercole et al., 2015; Rowell, Aughey, Hopkins, Stewart, & Cormack, 2017). In fact, athletes with fatigue-induced changes in neuromuscular function may employ compensatory adjustments to their jump strategy, thereby maintaining similar force production and achieving similar jump height (Gathercole et al., 2015; Rowell et al., 2017; Spencer et al., 2023). Bearing in mind the complexity of neuromuscular fatigue (Allen, Lamb, & Westerblad, 2008; Carroll et al., 2017; Gandevia, 2001; Nicol et al., 2006), it is possible that a limited analysis of CMJ metrics overlooks crucial fatigue-related changes within the neuromuscular system. Thus, contemporary perspectives advocate for a more holistic analysis of CMJ performance to provide insights into both CMJ outcome and movement strategy in response to neuromuscular fatigue (Bishop et al., 2023; Gathercole et al., 2015).

The systematic review and meta-analysis conducted by Silva et al. (2018) reported that a soccer match induces substantial muscle function impairments with alterations in muscle contractile properties and central motor output, resulting in CMJ performance decrements at match-end and until 48-72-h post-match. The impairment in this SSC jumping action reflects an inability to effectively transit from the eccentric to the concentric component. However, as different reviews showed (Marqués-Jiménez, Calleja-González, Arratibel, Delextrat, & Terrados, 2017; Nédélec et al., 2012; Silva et al., 2018), most studies using the CMJ test to examine neuromuscular fatigue in soccer players reported only a few CMJ metrics.

Moreover, defining a specific time frame for post-exercise recovery for CMJ performance is challenging as recovery time courses may differ within and between the CMJ metrics of interest. For instance, some output-orientated and force- and power-related CMJ metrics may not be affected immediately after a match and until 48-72-h post-match (Ishida, Bazyler, Sayers, Mizuguchi, & Gentles, 2021; Romagnoli et al., 2016; Spencer et al., 2023; Thorlund, Aagaard, & Madsen, 2009). Nevertheless, these findings were not universally confirmed. On one hand, post-match reductions in jump momentum and countermovement depth have been shown (Spencer et al., 2023). On the other hand, moderate to large decreases were observed between pre- and 12-h post-match in concentric impulse, relative and absolute peak power, concentric mean power, and reactive strength index modified (Ishida et al., 2021). Small to moderate decreases in peak power at 24-h and 48-h post-match were also reported (Russell et al., 2015). Accordingly, there is a need for a better understanding of the time course recovery of different CMJ metrics after a soccer match.

There is still a lack of scientific research focused on examining differences in both CMJ outcome and movement strategy between starters and non-starters soccer players after a match and during the recovery period. As fatigue management may be one of the substantial motivating factor for using substitutes at half-time or during the second half (Hills et al., 2018), a study examining the acute (i.e., post-match) and residual (i.e., 24 to 72-h post-match) effects of soccer match-play within players with partial or no match time would help practitioners to design appropriate compensatory sessions during the 48-h post-match period, tailor the implementation of recovery practices, and manage fatigue across the entire team. Therefore, the present study aimed to explore differences in the recovery kinetics of countermovement jump performance in starting and non-starting soccer players after the competition.

2. Materials and Methods

Participants — Twenty-one male outfield soccer players from a regional-level team were initially recruited to participate in this study. Inclusion criteria comprised the following: absence of any medical condition or injury, participation in three weekly training sessions (~90 min each) prior to each match, and inclusion in the starting line-up only in one match. Thus, data from twelve players were finally included in the statistical analysis (n = 12; age: 27.05 ± 4.31 years; height: 177.50 ± 4.56 cm; body mass: 71.48 ± 4.63 kg).

The research was conducted in compliance with the ethical principles of the Declaration of Helsinki (2013) and obtained approval from the Ethics Committee of Area Salud Valladolid Este (PI 22-2908). All participants provided written informed consent after receiving detailed information about the study objectives, procedures, potential benefits, and associated risks.

Design — A case series study was conducted. It included two data collection periods within a single competitive season (i.e., midseason and end-season), each encompassing one official match and the subsequent 48-h recovery period. Each participant's data was compared between two conditions: when they were a starter (included in the starting line-up) and when they were a non-starter (not included in the starting line-up, regardless of match playing time). Matches were played on a natural grass pitch (15:30 and 16:00 h). The coaching staff determined both the starting line-up and substitutions at their discretion, independent of any influence from the research team. Pre-match measurements were obtained on each morning of the match-day (10:00 h), and subsequent measurements were acquired immediately post-, at 24-h and at 48-h post-match. To control for circadian rhythmicity, post-, 24-h and 48-h post-match measurements were conducted at the same time point (18:00 h).

Participants were required to adhere to specific pre-study and in-study guidelines. In accordance with their regular in-season training regimen, participants engaged in a training session approximately 20-h prior to each match and were refrained from any form of formal training or strenuous physical activity during each 48-h recovery period. Participants attended matches and testing sessions in a fed and hydrated state, abstaining from alcohol, caffeine, and specific supplements for 24 hours prior to and during data collection. Recovery strategies were also restricted during this period.

Methodology — The CMJ testing protocol involved two trials interspersed with a two-min rest period. Trials were recorded on a Kistler Quattro Jump type 9290DD force plate using MARS for Quattro Jump & KiJump 5.2 software (Kistler Group, Winterthur, Switzerland), at a sampling frequency of 500 Hz. In each trial, participants adopted a pre-defined starting position (i.e., upright position with straight legs and hands on hips). Once this standardized position was adopted, participants executed a downward movement before the jump, performing a natural flexion before take off, and were asked to land in an upright position with bent knees. Since CMJ performance is influenced by the velocity and depth of the countermovement (Pérez-Castilla, Rojas, Gómez-Martínez, & García-Ramos, 2021; Pérez-Castilla, Weakley, García-Pinillos, Rojas, & García-Ramos, 2021), the CMJ depth was self-selected by each participant to preserve their preferred jump strategy and avoid introducing bias.

To familiarize participants with the testing procedures, CMJ test instructions were provided during the recruitment session (i.e., two weeks prior to the first data collection period). Participants subsequently practiced it during training sessions before the first data collection period. A standardized warm-up protocol was implemented, consisting of a general warm-up followed by dynamic active stretching (Pagaduan, Pojskić, Užičanin, & Babajić, 2012). Accordingly, participants completed five minutes of running followed by a seven-minute serie of dynamic active stretching exercises (straight leg march, butt kicks, carioca, high knees, reverse lunge with twist, power shuffle -step slide- and jogging with squats). Each exercise was performed in two sets of 20-s with a 10-s rest interval between both sets and exercises. A standardized laboratory environment was also employed to ensure consistent conditions.

According to previous research (Bishop et al., 2023; Gathercole et al., 2015), two specific sets of CMJ metrics were collected. From a performance monitoring perspective, the following output-orientated metrics were obtained: jump height (jump height achieved; cm), propulsive impulse (PropImp; product of force and time during ascent; Ns), absolute peak power (AbsPeakP; greatest power achieved during the jump; W), relative peak power (RelPeakP; greatest power achieved during the jump divided by participant's body mass; $W \cdot kg^{-1}$), and peak rate of force development (PeakRFD; the greatest amount of force in a given amount of time; $N \cdot s^{-1}$). From a neuromuscular fatigue monitoring perspective, the following time-based metrics were obtained: time to peak force (TPeakF; time from jump initiation -start of movement- to peak force; s), time to take off (TTakeOff; time from jump initiation -start of movement- to take off; s), propulsive phase duration (PropPhDur; time spent during ascent prior to take off; s), reactive strength index modified (RSImod; ratio of jump height to contraction time or time spent from jump initiation -start of movement- to take off), and flight time to contraction time ratio (FT:CT; ratio of flight time to contraction time or time spent from jump initiation -start of movement- to take off). For each metric, the mean value of both trials was considered for statistical analysis (Claudino et al., 2017).

Statistical Analysis — Descriptive statistics using mean (M) and standard deviation (SD) were calculated for all CMJ performance metrics. On one hand, time-related changes in performance within each group were determined using a repeated-measures analysis of variance (ANOVA) with Holm post hoc analysis and the Cohen's d effect size (ES) statistic (Cohen, 2013; Vickers, 2001). Cohen's d was interpreted as trivial (<0.2), small (0.2-0.5), moderate (0.5-0.8), and large (>0.8) (Cohen, 2013). On the other hand, group differences in performance impairments at post-match, 24-h, and 48-h post-match were determined by conducting an analysis of covariance (ANCOVA) with Holm post hoc analysis and partial eta squared (η^2p), using pre-match values as covariates (Vickers, 2001). η^2p was interpreted as trivial (<0.0099), small (0.0099 0.0588), medium (0.0588–0.1379), and large (>0.1379) (Cohen, 2013; Richardson, 2011). Statistical analysis was conducted using raw data, but figures were created using percentage change obtained from mean baseline scores (Vickers, 2001). All data were analysed using JASP 0.16.3.0 software (University of Amsterdam, Amsterdam, Netherlands). Statistical significance was set at $p < 0.05$.

3. Results

Match playing time was significantly higher in starters with respect to non-starters (81.58 ± 18.48 vs. 24.33 ± 18.48 min.; d = 2.913, large; $p < 0.001$).

Table 1 shows time-related changes in CMJ metrics in starters and non-starters. CMJ height was significantly lower in starters at 24-h post-match compared with pre-match (F = 8.253; d = -1.079, large; $p < 0.001$), post-match (F = 8.253; d = -0.935, large; p = 0.002) and 48-h post-match values (F = 8.253; d = -0.861, large; p = 0.005). PropImp was significantly decreased in starters at 24-h post-match compared with pre-match (F = 7.434; d = -0.640, moderate; $p < 0.001$) and 48-h post-match values (F = 7.434; d = -0.463, small; p = 0.011). No significant differences were found in the non-starters group.

Differences in responses between starters and non-starters groups are plotted in Figure 1. After adjusting for differences at pre-match baseline, there were significant differences between groups in PropPhDur at post-match (F = 4.936; η^2p = -0.190, large; p = 0.037), in CMJ height (F = 6.476; η^2p = -0.236, large; p = 0.019) and PropImp at 24-h post-match (F = 9.804; η^2p = -0.318, large; p = 0.005), and in AbsPeakP at 48-h post-match (F = 4.708; η^2p = 0.183, large; p = 0.042).

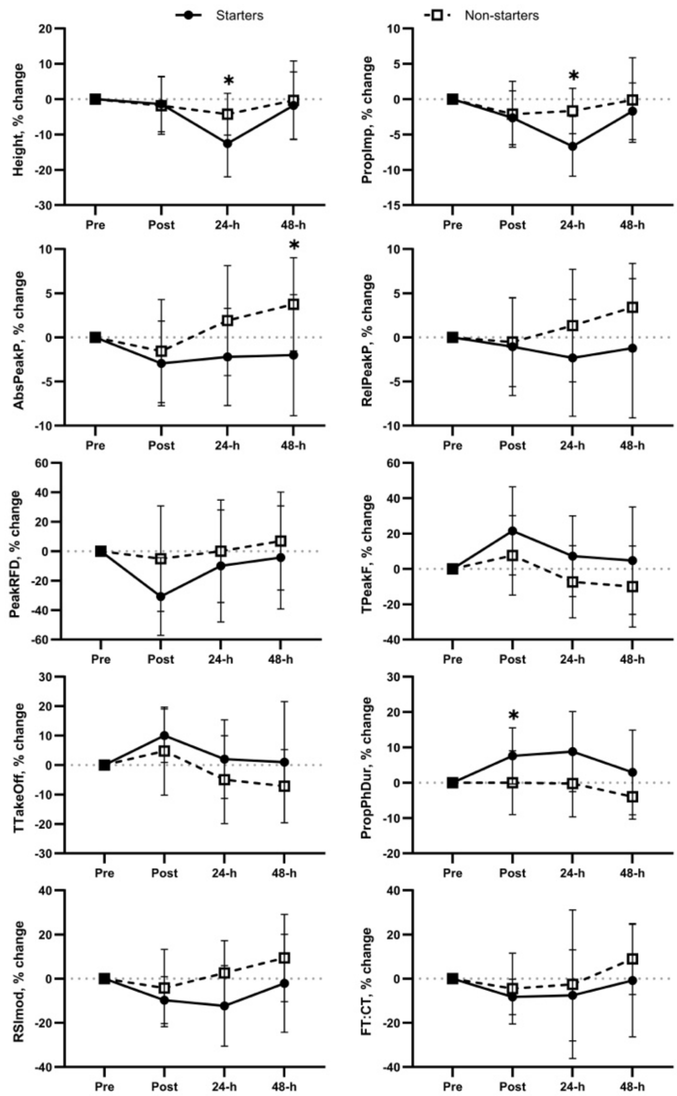

Figure 1. Percentage changes in CMJ metrics between starters and non-starters. Data are presented as mean (M) and standard deviation (SD). * Significant difference between starters and non-starters adjusted for baseline.

4. Discussion

The present study aimed to explore differences in the recovery kinetics of countermovement jump performance in starting and non-starting soccer players after the competition. Both jump outcome and movement strategy responses to neuromuscular fatigue evidenced a faster recovery of CMJ performance in non-starters players, which should be considered to optimize training periodization during the 48-h post-match period

Table 1. Time-related changes in CMJ metrics in starters and non-starters.

Metric	Time point	Starters M ± SD	Non-starters M ± SD
Height (cm)	Pre	0.40 ± 0.06	0.38 ± 0.04
	Post	0.39 ± 0.06	0.37 ± 0.03
	24-h	0.34 ± 0.05 [a b]	0.37 ± 0.04
	48-h	0.38 ± 0.05 [c]	0.38 ± 0.05
PropImp (Ns)	Pre	202.27 ± 26.60	197.29 ± 16.84
	Post	196.77 ± 25.27	192.87 ± 16.01
	24-h	188.43 ± 22.92 [a]	194.16 ± 20.01
	48-h	198.45 ± 23.86 [c]	196.89 ± 18.86
AbsPeakP (W)	Pre	4099.67 ± 680.88	3809.67 ± 362.33
	Post	3986.00 ± 723.07	3745.00 ± 367.75
	24-h	4009.08 ± 687.52	3891.63 ± 512.85
	48-h	4018.08 ±710.26	3955.92 ± 464.29
RelPeakP ($W \cdot kg^{-1}$)	Pre	56.01 ± 6.78	52.73 ± 4.28
	Post	55.52 ± 8.17	52.44 ± 4.87
	24-h	54.70 ± 7.22	53.50 ± 6.07
	48-h	55.26 ± 7.38	54.59 ± 5.84
PeakRFD ($N \cdot s^{-1}$)	Pre	14716.58 ± 9430.09	9687.50 ± 3434.50
	Post	10157.58 ± 5183.75	8897.17 ± 3607.35
	24-h	13246.79 ± 6435.46	9678.46 ± 3188.35
	48-h	14096.46 ± 6824.14	10358.75 ± 3074.62
TPeakF (s)	Pre	0.60 ± 0.12	0.75 ± 0.18
	Post	0.72 ± 0.18	0.79 ± 0.22
	24-h	0.64 ± 0.16	0.69 ± 0.21
	48-h	0.62 ± 0.18	0.65 ± 0.15
TTakeOff (s)	Pre	0.84 ± 0.10	0.95 ± 0.14
	Post	0.92 ± 0.13	0.99 ± 0.20
	24-h	0.85 ± 0.13	0.90 ± 0.19
	48-h	0.84 ± 0.15	0.87 ± 0.13
PropPhDur (s)	Pre	0.25 ± 0.02	0.29 ± 0.03
	Post	0.27 ± 0.03	0.29 ± 0.04
	24-h	0.28 ± 0.03	0.29 ± 0.04
	48-h	0.26 ± 0.03	0.28 ± 0.03
RSImod	Pre	0.48 ± 0.13	0.41 ± 0.08
	Post	0.44 ± 0.12	0.39 ± 0.10
	24-h	0.42 ± 0.11	0.43 ± 0.12
	48-h	0.47 ± 0.10	0.44 ± 0.08
FT:CT	Pre	0.68 ± 0.12	0.61 ± 0.11
	Post	0.62 ± 0.12	0.58 ± 0.14
	24-h	0.61 ± 0.12	0.59 ± 0.24
	48-h	0.65 ± 0.14	0.65 ± 0.09

AbsPeakP: absolute peak power; FT:CT: flight time to contraction time ratio; M: mean; PeakRFD: peak rate of force development; PropImp: propulsive impulse; PropPhDur: propulsive phase duration; RelPeakP: relative peak power; RSImod: reactive strength index modified; SD: standard deviation; TPeakF: time to peak force; TTakeOff: time to take off.

[a] Significant difference from pre-match ($p < 0.05$); [b] Significant difference from post-match ($p < 0.05$); [c] Significant difference from 24-h post-match ($p < 0.05$).

The ability of starters and non-starters to maintain the CMJ outcome immediately after the match (i.e., CMJ height, PropImp, AbsPeakP, RelPeakP, PeakRFD) could be considered as an absence of neuromuscular fatigue in both groups. However, changes in time-related metrics may reveal a shift in neuromuscular strategy of a CMJ in response to fatigue (Gathercole et al., 2015). In this regard, the longer PropPhDur of starters players immediately after the match indicates that an alternative movement strategy was used. Specifically, starters spent longer during ascent prior to take off to produce the same output so could be considered fatigued. Regardless of mechanism, this finding confirms previous ones obtained with soccer players, which indicated that impairments to neuromuscular function may result in a reorganization of jump strategy in order to maintain a similar output (Rowell et al., 2017; Spencer et al., 2023). However, contrasting results have also been found (Thorlund et al., 2009). Thus, practitioners are encouraged to consider neuromuscular fatigue immediately after a soccer match as decreases in both jump output and movement strategy.

In contrast to the findings obtained at post-match, the present results show a significant decrease in CMJ height and PropImp at 24-h post-match compared to baseline only in the starters group, and both output-orientated metrics were lower at 24-h post-match in the starters group compared to the non-starters. Moreover, AbsPeakP was lower at 48-h post-match in the starters group compared to the non-starters. These results confirm the faster recovery of CMJ performance in non-starters players and suggest that residual (i.e., 24 to 72-h post-match) effects of soccer match-play on CMJ performance may be primarily explained by changes in CMJ outcome rather than by alterations in jump strategy as evidenced at post-match. This interesting finding highlights the complexity of neuromuscular fatigue evaluation and may be related to the biphasic SSC-recovery pattern (Nicol et al., 2006). Recovery following impaired SSC function follows a two-stage process, including an immediate and significant reduction in SSC function after exercise, followed by a phase of temporary improvement within 1-2-h that precedes a subsequent decline in performance, resulting in the greatest decrease in SSC function 48-72-h post-exercise (Nicol et al., 2006). However, this finding may be influenced by the reliability and sensitivity of both output-orientated and time-based metrics to detect fatigue-induced changes in neuromuscular performance (Franceschi et al., 2023; Gathercole et al., 2015; Rowell et al., 2017). In fact, small to large decreases in some output-orientated metrics from 12-h to 48-h post-match were previously detected in soccer players (Ishida et al., 2021; Russell et al., 2015), although contradictory results were also shown (Romagnoli et al., 2016). Therefore, a critical gap still exists in the current knowledge concerning the recovery kinetics of CMJ outcome and movement strategy after soccer matches.

A variety of fatigue-mechanisms, both central and peripheral in origin, have been proposed to explain changes in CMJ performance following soccer matches (Brownstein et al., 2017), although the causes of such responses are likely multifactorial (e.g., ion homeostasis within the muscle cell, metabolic disturbances, impaired excitation of the sarcolemma, impaired excitation–contraction coupling, stretch-reflex sensitivity-related reduction in muscle stiffness, exercise-induced muscle damage) (Avela, Kyröläinen, Komi, & Rama, 1999; Marqués-Jiménez et al., 2017; Mohr, Krustrup, & Bangsbo, 2005; Nicol et al., 2006). Notwithstanding, due to differences in match playing time, starters and non-starters are exposed to different metabolic, mechanical and neural stress levels. Starters may accumulate higher physical load compared to non-starters (Anderson et al., 2016), but substitutes may cover greater distances than those covered over the equivalent time period by starters and are able to perform more high-intensity running than during the equivalent period when they complete 90 min (Hills et al., 2018). These differences are particularly important due to the plausible influence that match running activities may exert on CMJ performance after a match and during the recovery period. Although contrasting results have been found (Brownstein et al., 2017; de Hoyo et al., 2016; Marqués-Jiménez, Calleja-González, Arratibel-Imaz, & Terrados, 2022; Varley, Lewin, Needham, Thorpe, & Burbeary, 2017; Wiig, Raastad, Luteberget, Ims, & Spencer, 2019), various studies reported relationships between some external load metrics and changes in CMJ height immediately post- (Rowell et al., 2017) and at 24-h post-match (Nédélec et al., 2014), changes in AbsPeakP at 24-h post-match (Russell et al., 2016; Shearer et al., 2017), and changes in both CMJ average concentric and eccentric forces at 30-min, 24-h post- and 48-h post-match (de Hoyo et al., 2016). Thus, the faster recovery of CMJ performance in non-starters players may derive from the different fatigue levels induced by the match's metabolic, mechanical and neural demands. However, this hypothesis remains speculative as determining the mechanisms responsible for the different responses in both CMJ outcome and movement strategy was beyond the aim of the present study.

5. Practical Applications.

From a practical perspective, the findings of the current study provide interesting information for optimizing training periodization. During the 48-h post-match period, the management of training load and content is critical, as the distinct needs of both starters and non-starters players should be considered. Contemporary training periodization models recognize this need for individualized post-match training loads, differentiating loading patterns for players with full match time vs. partial or no match time (Martín-García, Gómez Díaz, Bradley, Morera, & Casamichana, 2018; Stevens, de Ruiter, Twisk, Savelsbergh, & Beek, 2017). This distinction has led to the development of comprehensive frameworks for designing compensation sessions during the 48-h post-match period, customizing the session content to meet the specific physical demands of substitutes and non-playing players (Díaz-Serradilla et al., 2023; Lacome, Simpson, Cholley, Lambert, & Buchheit, 2018). Thus, the current findings ensure a better understanding of neuromuscular responses to soccer matches, which may guide the application of individualized post-match training load and content.

While providing a better insight into responses to neuromuscular fatigue induced by a soccer match, this study is not without limitations. Given the great individual response to fatigue and match-to-match variability shown in the literature (Claudino et al., 2017; Kellmann et al., 2018; Mann, Lamberts, & Lambert, 2014; Marqués-Jiménez et al., 2017; Skorski et al., 2019), the results obtained may be influenced by the small sample and number of observations. Future research needs to examine whether the observed findings remain applicable to other competitive levels (e.g., professional, elite) as well as whether they are age- or sex-specific (e.g., youth, senior, male, female). Moreover, the analysis of residual effects of soccer match-play may add interesting information to the current results, so further research should include more testing time points (e.g., 72 to 96-h post-match). Comparing neuromuscular responses among more groups (e.g., starters, non-starters with partial match playing time, non-starters with no match playing time) would also be welcome to transfer knowledge from sport science to sport practice.

6. Conclusions

The present study shows that, in response to neuromuscular fatigue induced by a soccer match, recovery kinetics of CMJ performance differ between starters and non-starters players. Compared to baseline, two output-orientated metrics (i.e., CMJ height, PropImp) were significantly decreased at 24-h post-match only in starters, while no significant time-related changes were found in non-starters. Moreover, some CMJ metrics exhibit different responses between starters and non-starters at each time point. On one hand, one time-based metric (i.e., PropPhDur) was longer at post-match in the starters group compared to the non-starters. On the other hand, some output-orientated metrics were lower at 24-h post-match (i.e., CMJ height, PropImp) and at 48-h post-match (i.e., AbsPeakP) in the starters group compared to the non-starters. Thus, both jump outcome and movement strategy responses to neuromuscular fatigue evidenced a faster recovery of CMJ performance in non-starters players.

Supplementary Materials: The datasets generated and/or analysed during this study are not publicly available, but access may be granted upon reasonable written request to the corresponding author.

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