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Research article

The Impact of Weekly Acceleration and Deceleration Loads on Neuromuscular Performance in Soccer: A Session-to-Session Analysis

Bo Tan [1], Anqiang Hu [2]✉ and Yafei Zheng [3]
[1] College of Physical Education and Health, Geely University of China, Chengdu, China; [2] Sichuan Tourism University, Chengdu, China; [3] ChengDu Sports University, Chengdu, China

Abstract
This study examined weekly variations in accelerations, decelerations, and neuromuscular performance in male under-19 soccer players. It also explored the relationship between accumulated acceleration and deceleration loads and fluctuations in neuromuscular performance across a weekly microcycle. A repeated-measures observational design was used over two consecutive weeks, involving 39 outfield players monitored via Global Navigation Satellite Systems. Neuromuscular performance was assessed through countermovement jump (CMJ), hamstring strength (HS), and delayed onset muscle soreness (DOMS), measured both before and after training on five days each week, following a consistent training structure. Significant post-training reductions in CMJ (all days $p < 0.001$) and HS (all days $p < 0.001$) were observed, with the greatest impairments occurring on MD-4 and MD-5, although CMJ showed a slight rebound on MD-5 compared to MD-4. DOMS ratings peaked on MD-3 ($F = 39.186$, $p < 0.001$), indicating a buildup of midweek fatigue. The highest numbers of accelerations ($F = 248.121$, $p < 0.001$) and decelerations ($F = 227.853$, $p < 0.001$) occurred on MD-4 and MD-5. However, no statistically significant correlations were found between daily acceleration/deceleration counts and changes in CMJ or HS performance. These findings suggest that while neuromuscular performance declines progressively throughout the week, no statistically significant correlations were found between impairments and the acceleration or deceleration load of individual training sessions. Instead, the cumulative effect and timing of high-intensity training may play a more substantial role in contributing to fatigue and neuromuscular decline.

Key words: Training load, monitoring, readiness, periodization, football.

Introduction

Soccer players perform numerous accelerations and decelerations during competitive matches, with studies reporting around 0.7 to 0.9 accelerations per minute and 0.8 to 1.0 decelerations per minute in elite men matches (Morgans et al., 2025). These high-intensity actions contribute significantly to players' total match workload, with accelerations accounting for 7-10% and decelerations for 5-7% of the total player load across all positions (Dalen et al., 2016). The average distance covered during acceleration is approximately 600 meters, while during deceleration it is around 768 meters (Dalen et al., 2016). The frequency and intensity of these actions vary by player position and match period, with a decrease in the final 15 minutes of play (Russell et al., 2016). In the context of training, sessions typically involve fewer accelerations and decelerations than matches, with these numbers decreasing as match day approaches (Silva et al., 2023). Small-sided games elicit higher acceleration and deceleration demands compared to other training drills (Silva et al., 2023). However, monitoring these actions can be importante for assessing training load, as they correlate with various physiological and subjective measures of exertion (Douchet et al., 2021). Interestingly, youth players may perform as many or more accelerations and decelerations as senior players during matches (Vigh-Larsen et al., 2018). Therefore, understanding these acceleration and deceleration profiles is important for developing position-specific training programs, as they provide a more comprehensive view of match demands than traditional time-motion analysis alone (Harper et al., 2019).

The frequency of accelerations and decelerations decreases in the final 15 minutes of play, suggesting fatigue (Russell et al., 2016). Importantly, the total number of accelerations and decelerations shows a strong relationship with creatine kinase levels, a marker of muscle damage, immediately post-match and up to 64 hours later (Varley et al., 2017). Additionally, these actions correlate with perceived wellness ratings 40 and 64 hours post-match (Varley et al., 2017). Although research in this area is limited, studies in other sports, such as Australian football, have observed that several physical load indices likely contribute to muscle damage during competition. Specifically, impacts greater than 3g and high-intensity running variables (i.e., deceleration, acceleration, and sprint distance) have been identified as the strongest predictors of post-match creatine kinase levels (Gastin et al., 2019).

Accelerations and decelerations impose distinct and substantial mechanical stresses on the musculoskeletal system, making them highly impactful for muscle damage and functional impairment (Young et al., 2012). While accelerations predominantly involve concentric muscle contractions to generate force and increase velocity, decelerations require intense eccentric and quasi-isometric contractions to rapidly reduce velocity, resulting in a possible greater muscular tension and higher susceptibility to fatigue and tissue microtrauma (Harper and Kiely, 2018). This eccentric loading during deceleration activities significantly elevates biomechanical strain, often exceeding that experienced during accelerations by up to 65% per metre of movement (Dalen et al., 2016), which may lead to greater cumulative muscle damage and decrements in neuromuscular function. Eccentric muscle actions are well-established generators of micro-level structural disruption, excitation-contraction uncoupling, and reduced force output,

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which align with the mechanisms of exercise-induced muscle damage (DOMS and prolonged strength loss) (Proske and Morgan, 2001; Stožer et al., 2020). In this context, countermovement jump (CMJ) performance serves as a functional indicator of stretch-shortening cycle efficiency, which is sensitive to impairments in explosive power following eccentric stress (Di Domenico et al., 2023), while hamstring strength (HS) directly reflects the capacity of muscle-such as the hamstrings—to produce force under eccentrically compromised conditions (Schmitt et al., 2012). Therefore, the weekly declines in CMJ and HS can plausibly be interpreted as functional manifestations of the accumulated eccentric loads imposed by frequent decelerations. Consequently, continuous attention to the extent of muscle damage and functional impairment over the course of the training week can be important to prevent the compounding effects of fatigue and microtrauma (Harper and Kiely, 2018).

In addition to the naturally high demands of accelerations and decelerations during a match, the specific structure of weekly periodization can significantly influence the extent of muscular strain, depending on the objectives defined for each day and the types of training drills used. For example, one study (Silva et al., 2024) found that matches involve the greatest number of high-intensity accelerations and decelerations. In contrast, small-sided games tend to elicit more high-intensity efforts from lower starting speeds, while compensation drills typically involve acceleration and deceleration efforts beginning at higher velocities. These findings suggest that different drills impose distinct load profiles that do not always replicate match demands. From a practical perspective, coaches deliberately manipulate drill type and intensity across the microcycle to balance physical conditioning, tactical preparation, and recovery. For instance, early-week sessions (e.g., MD-4) often emphasize high-intensity games or conditioning blocks to provide a strong physical stimulus, while later sessions (e.g., MD-1 and MD−2) prioritize tactical refinement and recovery to reduce cumulative fatigue prior to competition (M. Oliva-Lozano et al., 2022; Douchet et al., 2024). Since training drills vary across the week, this variability can also affect the frequency and intensity of accelerations and decelerations throughout the microcycle. For instance, a study analyzing weekly periodization reported that the absolute distances covered in accelerations and decelerations are highest early in the week (match day [MD]-4) and decrease substantially by the final training session before the match (MD-1). This reflects a periodization strategy aimed at reducing total load volume while maintaining the relative intensity - or density - of accelerations and decelerations to manage fatigue and optimize match readiness (Akenhead et al., 2016).

Although accelerations and decelerations have been associated with physiological stress, muscle damage markers, and subjective fatigue, previous research has rarely examined their direct relationship with objective neuromuscular performance measures such as countermovement jump (CMJ) and hamstring strength (HS), particularly in a session-to-session context across the weekly training cycle. Most existing studies focus on match demands or broad workload indices, leaving a gap in understanding how day-to-day variations in acceleration and deceleration loads influence neuromuscular readiness. This study addresses this gap by conducting repeated within-week assessments of CMJ, HS, and DOMS over two consecutive weeks in youth soccer players, providing novel insights into both the temporal patterns of neuromuscular impairment and their potential association with acceleration/deceleration loads. Based on the considerations outlined above, this study aimed to analyze the association between accumulated acceleration and deceleration training loads and neuromuscular impairment occurring after training in soccer players. Neuromuscular performance was assessed using countermovement jump (CMJ), hamstring strength (HS), and DOMS via questionnaire. As a secondary objective, the study sought to compare the magnitude of neuromuscular impairments before and after training across different days of the week, as well as to examine variations in acceleration and deceleration loads throughout the training week.

Methods

Experimental approach

The current study employed a descriptive, repeated-measures design in which the same players were assessed over two consecutive weeks, both of which followed an identical training periodization schedule. Specifically, the players were monitored using Global Navigation Satellite System technology to track physical demands - focusing on accelerations and decelerations - throughout training sessions. Additionally, on both training and rest days (five days per week), players were assessed for CMJ and HS before and after training sessions. Prior to each session, players also completed a DOMS scale evaluation. The two-week period was found to be consistent in terms of training structure, and this specific time frame was selected based on its practical suitability for data collection during the season. The same protocol was implemented in two different under-19 teams competing at the same regional and competitive level, allowing for a broader and more generalized context than studies focusing on a single team, which is common in this field. Given the descriptive nature of the study and its specific context, a convenience sampling approach was adopted to align with logistical considerations, such as obtaining permissions and aligning data collection with training schedules. Figure 1 presents the study design, including the number of training sessions analyzed and the neuromuscular performance and DOMS evaluations conducted throughout the process. As a descriptive study, the researchers were only involved in monitoring and evaluation and did not intervene in the training planning or implementation.

Participants

The study was conducted with two teams competing in provincial under-19 competitions, both of which follow similar training structures and organizational planning. Both teams had a similar weekly microcycle structure consisting of one official match and five structured training sessions (MD-5 to MD-1). The periodization strategy was also similar, with MD-4 and MD-3 used for high-intensity tactical and conditioning drills, MD-2 for tactical rehearsal and

Figure 1. Illustration of weekly monitoring and evaluation. MD: Match Day; DOMS: Delayed Onset Muscle Soreness; HS: Hamstring Strength; CMJ: Countermovement Jump.

set-pieces, and MD-1 for low-load pre-match activation. While individual drills were designed by each team's coaching staff, the session duration, sequencing, and overall objectives were consistent across both squads. After selecting these teams, invitations were sent to the technical staff and players, inviting them to participate in this descriptive study. Of the available players, 39 were ultimately included in the analysis. The inclusion criteria were established in the protocol and consisted of the following: (i) only outfield players were included; (ii) players had to participate in all training sessions during the two-week observation period; and (iii) players had to complete all scheduled assessment time points within the two weeks. The exclusion criteria were: (i) goalkeepers, due to their specialized position and differing physical demands profile; (ii) players recovering from injury or returning to play; and (iii) players who were injured or became injured during the study period.

From an initial pool of 46 available players, five were excluded because they were goalkeepers, and two were excluded due to injury at the time of the study. The final sample consisted of 39 male under-19 players, with the following characteristics: age 17.9 ± 0.6 years, height 177.3 ± 4.1 cm, weight 65.6 ± 3.9 kg, and playing experience 3.9 ± 1.1 years.

All players were informed about the study's methodology and explicitly told that participation was voluntary and that there would be no penalty for opting out. After receiving clarification, all participants provided written informed consent. The study protocol was reviewed and approved by the Ethics Committee of Chengdu Sport University, receiving the approval code〔2025〕135.

Neuromuscular assessments and delayed onset muscle soreness

The participants' neuromuscular performance was assessed in a controlled environment on all training days, as well as on rest days. To enable analysis of immediate effects and recovery, all players were tested before and after each session using the CMJ and HS assessments. To expedite the process, participants performed only two trials of both HS and CMJ, with 30 seconds of rest between trials. Although more trials are often recommended to maximize reliability, prior studies have shown that two maximal attempts are sufficient to yield reliable measures in both CMJ (Karim et al., 2019) and isometric hamstring strength testing (Miralles-Iborra et al., 2023), provided that athletes are familiarized with the procedures. All evaluations were conducted indoors in a specific room with support from the research team, following a consistent sequence of procedures to ensure replicability. Assessments were carried out 30 minutes prior to training sessions and 15 minutes after each session concluded. The pre-training assessment window was chosen to ensure players were tested under standardized conditions before warm-up, providing a stable baseline of neuromuscular status. The post-training assessments were conducted shortly after session completion to capture the acute effects of training load on neuromuscular performance, while avoiding potential confounding from short-term recovery processes or subsequent daily activities (Wu et al., 2019). Also, before each session, participants rated their DOMS levels using a questionnaire administered prior to the neuromuscular assessments.

Hamstrings strength

HS was assessed through maximal voluntary isometric contractions performed on a custom-built bench, with participants seated at 30° knee flexion and 90° hip flexion, following the procedures described in a reliability study (Miralles-Iborra et al., 2023). A portable load cell (maximal capacity 500 kg, resolution 24-bit, and frequency 160 Hz, Chronojump, Boscosystem, Spain), attached via a strap above the malleolus to a rigid bar, was used to collect force data as participants performed two 2-second maximal isometric knee flexion efforts using their dominant leg - previously identified as the leg capable of producing greater force - with a 30-second rest between repetitions. The load cell measured linear force output, capturing peak voluntary isometric contractions expressed in newtons. Participants were instructed to contract explosively while maintaining an upright torso. The mean force from both valid attempts was used for analysis.

Countermovement jump

Countermovement jump (CMJ) performance was evaluated using a contact platform (Chronojump, Boscosystem, Spain), which holds previously validated (Pueo et al., 2020). Participants began from an upright standing position and performed two maximal vertical jumps preceded by a rapid downward movement to engage the stretch-shortening cycle. They were instructed to jump as high and explosively as possible, keeping their hands on their hips to minimize arm swing effects. A 30-second rest period was given between jumps to reduce fatigue. Jump height (cm) was recorded, with the mean value from both valid attempts used for analysis.

Delayed onset muscle soreness questionnaire

A 7-point Likert scale (ranging from 0 to 6, where 0 indicates no muscle soreness and 6 indicates maximal soreness with restricted range of motion) was used to assess perceived DOMS. Athletes completed the scale individually each morning in their rooms, prior to breakfast and before beginning any daily activities, to standardize reporting conditions and minimize variability due to training or external factors. Prior to data collection, participants were familiarized with the scale, including the verbal descriptions associated with each score, to ensure accurate and consistent reporting. A researcher supervised the process to ensure clarity and address any questions during scoring.

Acceleration and deceleration monitoring

The total number of accelerations and decelerations was monitored using a 10 Hz GNSS sensor (ASI, Switzerland). The device had previously been validated for accuracy and reliability against established GNSS systems, demonstrating consistent performance across various movement measures (Willmott et al., 2018). Notably, 10 Hz GPS/GNSS units have been shown to provide sufficient temporal resolution and measurement sensitivity to accurately detect rapid accelerations and decelerations, even during short, high-intensity actions common in team sports (Howe et al., 2020). To minimize inter-device variability, each player consistently used the same GNSS unit throughout the study. The sensor was placed in a dedicated vest, positioned on the upper back of each player. The GNSS device was activated at the beginning of each training session and deactivated at the end. The total counts of accelerations and decelerations recorded during each session were used for subsequent analysis.

Training content varied systematically across the weekly microcycle in line with common periodization practices. On MD-5, sessions were primarily devoted to recovery and technical-tactical activities at low intensity (e.g., rondos, passing patterns), generating relatively few accelerations or decelerations. MD-4 and MD-3 typically emphasized physical conditioning and high-intensity tactical drills, including small-sided games and repeated sprint activities, which produced the highest counts of accelerations and decelerations. MD-2 was generally focused on tactical rehearsal and set-piece organization, involving moderate intensity and fewer high-speed transitions. MD-1 was structured as a pre-match activation session, with emphasis on low-load technical exercises and dynamic stretching.

Statistical analysis

The different days of the week were classified relative to match day (MD), with one day prior labeled as MD-1, two days prior as MD-2, and so on. As data were collected over two consecutive weeks, the average values for each corresponding day (e.g., MD-3, MD-2, etc.) were calculated and used for further analysis. The Shapiro–Wilk test was performed to assess the normality of the data. To evaluate differences in the number of accelerations and decelerations, as well as CMJ, HS, and DOMS values across MD days, a repeated measures two way (for the case of CMJ and HS, since they were also analyzed before and after the training)) and one-way ANOVA (for the case of accelerations, decelerations and DOMS) was conducted. When a significant main effect was found, Bonferroni-adjusted post hoc comparisons were performed to identify specific differences between days. Effect sizes were calculated using partial eta squared (η^2), and interpreted as small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), and large ($\eta^2 = 0.14$). Additionally, Pearson product–moment correlation analyses were conducted to examine relationships between the accumulated number of accelerations and decelerations on each training day and the subsequent changes (post–pre values) in CMJ and HS performance. Furthermore, correlations were also analyzed between accelerations and decelerations on a given day and DOMS scores on the following day. The magnitude of the Pearson correlation coefficient (r) was interpreted as follows: trivial (< 0.1), small (0.1 - 0.3), moderate (0.3 - 0.5), large (0.5 - 0.7), very large (0.7 - 0.9), and nearly perfect (> 0.9). All statistical analyses were performed using SPSS software (IBM SPSS Statistics, Version 27.0), with significance set at $p < 0.05$.

Results

A significant interaction effect was found between weekday and prepost training, $F = 1217.549$, $p < 0.001$, $\eta p2 = 0.970$ for comparisons of CMJ. Additionally, a significant interaction effect was found between weekday and prepost training, $F = 1214.372$, $p < 0.001$, $\eta p2 = 0.970$. Table 1 shows the descriptive statistics of CMJ and HS pre and post training sessions over the week days.

The Figure 2 illustrates the progressive decline in neuromuscular performance across the week, with the greatest decrements observed on MD-4 (CMJ - 7.9%, HS - 7.9%) and MD-5 (CMJ - 7.8%, HS - 7.9%).

Post-training CMJ height was significantly lower than pre-training CMJ height for MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). For pre-training CMJ, there was a general decreasing trend in jump height from MD-1 to MD-4. Specifically, MD-1 CMJ was significantly higher than MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), and MD-4 ($p < 0.001$). Similarly, MD-2 was significantly higher than MD-3 ($p < 0.001$) and MD-4 ($p < 0.001$), and MD-3 was significantly higher than MD-4 ($p < 0.001$). Interestingly, pre-training CMJ on MD-5 was significantly lower than MD-1, MD-2, MD-3, and MD-4. However, no significant difference ($p > 0.05$) was found between MD-1 and MD-5 pre-training CMJ height. Post-training CMJ was significantly higher on MD-1 compared to MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). This downward trend continued, with MD-2 being significantly higher than MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). Likewise, MD-3 was significantly higher than MD-4 ($p < 0.001$) and MD-5 ($p < 0.001$). Post-training CMJ on MD-5 was significantly higher than MD-4 ($p < 0.001$) but remained significantly lower than MD-1, MD-2, and MD-3.

Table 1. Means (±Standard Deviation) for Countermovement Jump (CMJ) height and Hamstring Strength (HS) across weekdays and training stages.

Weekday	Training Stage	CMJ Height (cm)	Hamstring Strength (N)
MD-1	Pre-training	34.69 (2.87)	323.31 (30.09)
	Post-training	34.49 (2.86)	321.27 (30.00)
MD-2	Pre-training	34.37 (2.85)	320.34 (29.97)
	Post-training	33.84 (2.80)	315.04 (29.57)
MD-3	Pre-training	33.88 (2.84)	315.89 (29.88)
	Post-training	32.78 (2.75)	305.59 (28.96)
MD-4	Pre-training	33.42 (2.91)	311.56 (30.36)
	Post-training	30.79 (2.79)	286.93 (28.86)
MD-5	Pre-training	34.66 (2.90)	323.28 (30.23)
	Post-training	31.95 (2.71)	297.83 (28.08)

MD: match day.

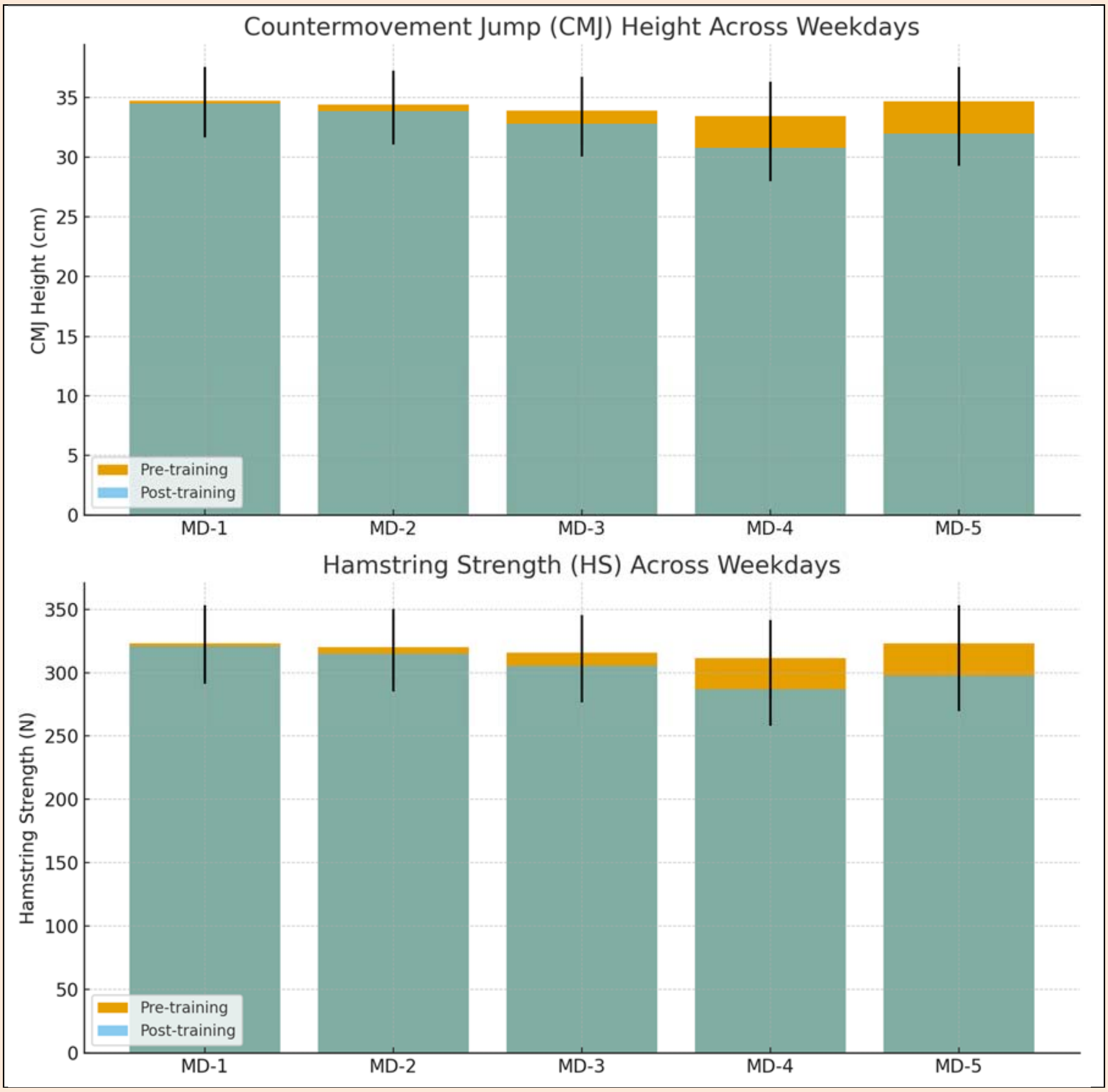

Figure 2. Countermovement jump (CMJ) height (top) and hamstring strength (HS) (bottom) across weekdays. Bars represent mean values with standard deviations. Pre-training and post-training measures are shown for each match day relative to competition (MD-1 to MD-5).

Analysis of the differences between pre-training and post-training hamstring strength for each weekday revealed consistent and significant reductions in strength following training across all days. Specifically, post-training HS was significantly lower than pre-training HS for MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). A clear trend emerged where the magnitude of the decrease in HS from pre to post-training progressively increased across the week, with the smallest reduction observed on MD-1 and the largest reductions on MD-4 and MD-5. For pre-training HS, there was a general decreasing trend in strength from MD-1 to MD-4. Specifically, MD-1 HS was significantly higher than MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), and MD-4 ($p < 0.001$). Similarly, MD-2 was significantly higher than MD-3 ($p < 0.001$) and MD-4 ($p < 0.001$), and MD-3 was significantly higher than MD-4 ($p < 0.001$). Interestingly, pre-training HS on MD-5 was significantly lower than MD-1, MD-2, MD-3, and MD-4. However, no significant difference ($p > 0.05$) was found between MD-1 and MD-5 pre-training HS. Post-training HS was significantly higher on MD-1 compared to MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). This downward trend continued, with MD-2 being significantly higher than MD-3 ($p < 0.001$), MD-4 ($p < 0.001$), and MD-5 ($p < 0.001$). Likewise, MD-3 was significantly higher than MD-4 ($p < 0.001$) and MD-5 ($p < 0.001$). The most substantial post-training reductions in hamstring strength were observed later in the week, particularly on MD-4 and MD-5. Post-training HS on MD-5 was significantly lower than MD-1, MD-2, and MD-3, but significantly higher than MD-4.

The one-way repeated measures ANOVA revealed a statistically significant effect of weekday on DOMS ratings, $F = 39.186$, $p < 0.001$, $\eta p^2 = 0.508$. Table 2 presents the descriptive statistics (mean and standard deviation) for DOMS ratings across five different weekdays (MD-1 to MD-5). The highest DOMS values were observed on MD-3 (mean = 1.04), which were significantly higher than all other days ($p < 0.001$). In addition, DOMS was slightly but significantly higher on MD-2 (mean = 0.27, $p = 0.009$), MD-4 (mean = 0.26, $p = 0.010$), and MD-5 (mean = 0.22, $p = 0.027$) compared to MD-1 (mean = 0.09). No other pairwise differences reached statistical significance.

The one-way repeated measures ANOVA revealed a statistically significant effect of weekday on accelerations number, $F = 248.121$, $p < 0.001$, $\eta p2 = 0.867$. Analysis of the mean differences in accelerations number between the different weekdays revealed several significant findings. The highest number of accelerations was observed on MD-4 (mean = 44.00), which was significantly higher than all other days: MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), and MD-5 ($p < 0.001$). Furthermore, MD-5 (mean = 37.72) showed significantly higher accelerations compared to MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), and MD-3 ($p < 0.001$). Comparing the later days of the week, MD-1 (mean = 30.74) was significantly higher than MD-2 ($p < 0.001$), but no significant difference was found between MD-1 and MD-3. MD-3 (mean = 30.03) was also significantly higher than MD-2 ($p < 0.001$).

The one-way repeated measures ANOVA revealed a statistically significant effect of weekday on decelerations number, $F = 227.853$, $p < 0.001$, $\eta p2 = 0.857$. Table 3 presents accelerations and decelerations number across weekdays. The highest number of decelerations was observed on MD-4 (mean = 43.65), which was significantly higher than all other days: MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), MD-3 ($p < 0.001$), and MD-5 ($p < 0.001$). Furthermore, MD-5 (mean = 38.74) showed significantly higher decelerations compared to MD-1 ($p < 0.001$), MD-2 ($p < 0.001$), and MD-3 ($p < 0.001$). Comparing the earlier days of the week, MD-1 (mean = 30.63) was significantly higher than MD-2 ($p < 0.001$), but no significant difference was found between MD-1 and MD-3. MD-3 (mean = 30.40) was also significantly higher than MD-2 ($p < 0.001$).

Table 2. Descriptive statistics for Delayed Onset Muscle Soreness (DOMS) ratings.

Variable	Mean	Std. Deviation
DOMS (N) MD-1	0.09	0.19
DOMS (N) MD-2	0.23	0.38
DOMS (N) MD-3	1.04	0.86
DOMS (N) MD-4	0.26	0.32
DOMS (N) MD-5	0.22	0.28

MD: match day.

Table 3. Mean (and Standard Deviation) for accelerations and decelerations number across weekdays.

Weekday	Accelerations Number (n) Mean (SD)	Decelerations Number (n) Mean (SD)
MD-1	30.73 (4.07)	30.63 (3.87)
MD-2	26.55 (3.60)	26.72 (3.31)
MD-3	30.03 (2.82)	30.40 (2.62)
MD-4	44.00 (6.86)	43.65 (6.95)
MD-5	37.72 (5.56)	38.74 (5.31)

MD: match day

For all training days, neither accelerations nor decelerations showed statistically significant correlations with post–pre differences in CMJ or HS performance. However, on MD-5 there was a trend toward moderate negative correlations between accelerations and both CMJ ($r = -0.30$, $p = 0.068$) and HS ($r = -0.32$, $p = 0.050$), as well as between decelerations and both CMJ ($r = -0.27$, $p = 0.092$) and HS ($r = -0.29$, $p = 0.077$). While these values did not reach statistical significance, they suggest a possible relationship between higher mechanical loads late in the week and greater neuromuscular impairments, which warrants further investigation. These findings indicate that acceleration and deceleration volume alone cannot fully account for neuromuscular changes, implying that additional factors may be at play. Table 4 shows the Pearson correlation coefficients between accelerations, decelerations, and the mean differences (post–pre training) for CMJ and hamstring strength for each respective training day.

Discussion

The main objective of this study was to examine the association between accumulated acceleration and deceleration loads and subsequent neuromuscular impairments in soccer players, as measured by CMJ, HS, and DOMS. A secondary aim was to evaluate how these neuromuscular responses varied across the training week. The findings revealed consistent and significant post-training decrements

Table 4. **Correlations of accelerations (ACC) and decelerations (DEC) with post-pre session mean difference Countermovement Jump Height (CMJ) and Hamstring Strength (HS) Mean Difference (by Training Day)**

Training Day	Variable Pair	ΔCMJ Mean Difference (r)	CMJ Sig. (2-tailed)	ΔHS Mean Difference (r)	HS Sig. (2-tailed)
Day 1	ACC MD-1	-0.178	0.277	-0.113	0.493
	DEC MD-1	-0.178	0.278	-0.085	0.606
Day 2	ACC MD-2	-0.084	0.610	0.172	0.295
	DEC MD-2	-0.003	0.986	0.117	0.480
Day 3	ACC MD-3	-0.155	0.345	-0.140	0.394
	DEC MD-3	-0.059	0.721	-0.044	0.790
Day 4	ACC MD-4	0.004	0.978	-0.080	0.630
	DEC MD-4	0.009	0.956	-0.072	0.661
Day 5	ACC MD-5	-0.296	0.068	-0.316	0.050
	DEC MD-5	-0.273	0.092	-0.287	0.077

MD: match day.

in both CMJ and HS across all training days, with the most pronounced reductions occurring on MD-4 and MD-5. These impairments coincided with the highest recorded volumes of accelerations and decelerations, particularly on MD-4, suggesting a cumulative fatigue effect. However, despite clear temporal trends in neuromuscular performance and external load, no statistically significant correlations were found between acceleration/deceleration measures and acute neuromuscular decrements. This indicates that while external load may contribute to overall fatigue patterns throughout the week, it may not be a direct predictor of immediate neuromuscular impairment. Moreover, DOMS ratings peaked on MD-3, with lower - but still elevated - values on surrounding days, further highlighting the fluctuating physiological demands imposed by weekly training structure. This midweek peak in soreness may also serve as an early indicator of the subsequent neuromuscular impairments observed on MD-4 and MD-5, as previous research has shown that elevated muscle soreness at 40–64 hours post-match is associated with reductions in CMJ performance and neuromuscular function (Varley et al., 2017).

Throughout the training week, both CMJ height and HS exhibited a progressive decline from MD-1 through MD-4, with partial recovery or attenuation of decline observed on MD-5. Pre-training values for both CMJ and HS were highest on MD-1 and significantly declined over the subsequent days, with the lowest neuromuscular outputs recorded on MD-4. Interestingly, MD-5 showed a slight rebound in both measures, though still below MD-1 values, suggesting some degree of recovery despite ongoing training. This rebound likely reflects the lighter content of MD-5 sessions - typically focused on technical-tactical refinement and low-intensity activation drills - combined with the onset of physiological recovery in anticipation of match day. Supporting this, a study (Beltran-Valls et al., 2020) found that a 2-week step taper in amateur soccer players led to significant improvements in muscle power (CMJ power), acceleration, and reduced stress perceptions compared to those who continued regular load ($p \leq 0.01$ for power; $p \leq 0.05$ for acceleration). Our findings are also consistent with prior research indicating that neuromuscular performance can be suppressed midweek due to cumulative training loads and insufficient recovery (Nedelec et al., 2014). For instance, a previous study revealed that emphasizing eccentric exercises may lead to an immediate decrease in jump and sprint performance. Accumulated neuromuscular fatigue resulting from eccentric muscle damage and high-intensity mechanical stress likely impairs muscle contractility and motor unit recruitment (Brownstein, Millet and Thomas, 2021). Additionally, elevated markers of muscle soreness and perceived fatigue midweek may reflect altered delayed recovery, which may compromise performance output (Nguyen et al., 2009).

The distribution of accelerations and decelerations across the training week revealed that the highest volumes occurred on MD-4, followed by MD-5, with significantly lower counts on the days closer to match day, particularly MD-1 and MD-2. This pattern is consistent with typical periodization in soccer, where the early to midweek sessions (MD-5 and MD-4) are designed to impose higher mechanical and neuromuscular loads through drills requiring frequent accelerations and decelerations, such as high-intensity interval training, small-sided games, and tactical work aimed at conditioning (Martín-García et al., 2018). The rationale may be to elicit a training stimulus when there is sufficient time for recovery before competition. As the week progresses toward match day (MD-1 and MD-2), training load is intentionally reduced to allow recovery and tapering, with lower volumes of high-intensity accelerations and decelerations, focusing instead on technical-tactical preparation and regeneration (Oliva-Lozano et al., 2022). However, it should be noted that MD-1 still showed higher acceleration counts than MD-2 in our data. This likely reflects the use of pre-match activation drills, which may include brief explosive efforts designed to prepare players for competition, whereas MD-2 sessions were primarily tactical and less reliant on high-frequency accelerations. Thus, the tapering pattern is not strictly linear but reflects the different objectives of late-week training days. The relatively high load observed on MD-5 compared to the days closer to the match may suggest the progressive buildup of training stress early in the week, enabling players to accumulate sufficient stimulus before entering the taper phase, aliging with the results of a study in professional players (Akenhead et al., 2016).

The analysis of correlations between the number of accelerations and decelerations and the changes in neuromuscular performance (post-pre training differences in CMJ height and hamstring strength) revealed no statistically significant relationships across the training days. Although there was a trend toward moderate negative correlations on MD-5 for both CMJ and HS, these did not reach statistical significance. This suggests that the acute neuromuscular impairments observed after training sessions cannot be directly explained by the volume of accelerations and decelerations alone. One possible explanation is that accelerations and decelerations, while mechanically demanding, represent only one component of the overall training load (Teixeira et al., 2023). Additionally, the lack of significant correlations may reflect a threshold effect, where the neuromuscular system tolerates a certain load of accelerations/decelerations without acute impairment directly caused by such movements (Djaoui et al., 2022). Finally, neuromuscular performance tests such as CMJ and HS may be influenced by multiple concurrent fatigue mechanisms, including metabolic stress, central nervous system fatigue, and muscle damage from other training elements beyond accelerations/decelerations (Ascensão et al., 2008). It is also plausible that the effects of frequent accelerations and decelerations accumulate over time and manifest with a delay, rather than producing immediate decrements. In this sense, the absence of same-day correlations does not exclude a causal role of mechanical load, but instead suggests that neuromuscular impairments may result from cumulative or lagged effects across multiple sessions, consistent with prior observations that muscle damage markers often peak 24 - 72 hours after eccentric loading (Howatson and van Someren, 2008).

This study has several limitations that should be considered. First, the sample size was modest and restricted to competitive under-19 male players. While this reflects real-world academy training environments, it limits the generalizability of findings to other age groups, female players, or senior/professional levels. This sample-related constraint represents a greater threat to external validity than the choice of specific load metrics. Second, a convenience sampling approach was used, which, while common in applied sports science, further restricts generalizability. Third, the monitoring period was limited to two consecutive weeks; although this period was representative of a typical in-season microcycle, a longer observation window would strengthen the external validity of the findings. Fourth, only two trials of CMJ and HS were conducted at each time point to minimize fatigue and testing burden, which may have reduced measurement precision despite acceptable reliability in familiarized athletes. Finally, while our analysis focused exclusively on accelerations and decelerations, this was a deliberate design choice to isolate their specific effects on neuromuscular function. Future studies should extend this work by incorporating additional load metrics (e.g., high-speed running, total distance, biochemical markers) to provide a more holistic understanding of training-induced fatigue. From a practical standpoint, the findings highlight the importance of carefully structuring training loads across the week, with particular attention to MD-4 and MD-5, where the greatest impairments in CMJ and HS were observed. Managing acceleration and deceleration demands on these days is critical, while ensuring adequate tapering before match day may help to optimize recovery and readiness.

Conclusion

In conclusion, the present study found no statistically significant correlations between accelerations/decelerations and acute neuromuscular impairments, although consistent decrements in CMJ and HS were observed across the week, particularly on MD-4 and MD-5. In contrast, DOMS ratings peaked earlier, on MD-3, indicating that subjective perceptions of muscle soreness did not align perfectly with the timing of the greatest objective neuromuscular impairments. A trend toward moderate negative correlations was noted on MD-5, suggesting that higher late-week acceleration and deceleration loads may contribute to neuromuscular decline, even if this relationship did not reach statistical significance. These findings indicate that accelerations and decelerations alone may not fully explain neuromuscular fatigue, and that other factors such as total distance covered, high-intensity running, or even non-training stressors (e.g., academic or psychosocial demands) may play a more predictive role. Future research should integrate these additional variables to develop a more comprehensive understanding of the determinants of neuromuscular fatigue in soccer and explore how individualized load monitoring strategies can be applied to better capture inter-individual variability in training responses.

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Key points

- Despite significant declines in countermovement jump (CMJ) and hamstring strength (HS) performance, no correlations were found between the acceleration and deceleration loads during individual training sessions and these impairments.
- Neuromuscular performance deteriorated progressively throughout the week, with peak muscle soreness and fatigue on midweek (MD-3), highlighting the importance of session timing and cumulative training load in influencing fatigue and performance decline.

AUTHOR BIOGRAPHY

Bo TAN
Employment
Geely University of China, Chengdu, 641400, China
Degree
PhD
Research interests
Sports training, sports psychology, etc.
E-mail: 920514879@qq.com

Anqiang HU
Employment
Sichuan Tourism University, Chengdu, 610100, China
Degree
MEd
Research interests
Recreational sports, water sports, etc.
E-mail: 398141252@qq.com

Yafei ZHENG
Employment
ChengDu Sports Univ, Chengdu 610041, Peoples R China
Degree
MEd
Research interests
physical education, etc.
E-mail: 313518278@qq.com

✉ **Anqiang Hu**
Sichuan Tourism University, Chengdu, 610100, China