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ORIGINAL ARTICLE

Effects of high-intensity training on neuromuscular fatigue in early adolescent soccer players

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ABSTRACT

Purpose: This study aimed to assess the extent of neuromuscular fatigue in early adolescent soccer players following a high-intensity training session that combined Speed, Agility, and Quickness (SAQ) drills with small-sided game (SSG). Method: Fourteen youth soccer players participated in the study (year: 13.21 ± 0.69 years, height: 156.28 ± 3.95 cm, weight: 47.14 ± 10.77 kg). A within-subjects, repeated-measures design was used to evaluate the variations in neuromuscular fatigue, assessments were conducted immediately before the training session, immediately after, one hour post-session, 24 hours post-session, and 48 hours post-session. The study employed the 10-meter speed test and the Countermovement jump (CMJ) test, both recognized as valid and reliable indicators of neuromuscular fatigue. Statistical analysis was performed using SPSS software. Results: The results revealed statistically significant differences in CMJ test scores between the initial measurement (pre-session) and one hour post-training ($p < .05$), as well as 24 hours post-training ($p < .05$). Conclusion: The high-intensity training session for youth soccer players induced significant neuromuscular fatigue, persisting up to 24 hours. These findings underscore the importance of monitoring neuromuscular fatigue to optimize recovery and reduce the risk of overexertion and injuries in early adolescent soccer players.

Keywords: Performance analysis, Neuromuscular fatigue, Small-sided games, Speed-agility-quickness, Youth athletes.

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INTRODUCTION

Youth participation in soccer stands as one of FIFA's emphasized essential components for the future of the sport (FIFA, n.d.). Soccer helps develop skills, physical fitness, and overall growth (Hammami et al., 2013) and contributes to their psychological and social well-being (Eime et al., 2013). However, this participation isn't without risks, as the physical demands of training and matches expose children and adolescents to potential injuries and health concerns (Wik et al., 2023; Mandorino et al., 2023). It's crucial to explore factors like neuromuscular fatigue, which significantly impact the well-being and performance of these budding athletes.

Neuromuscular fatigue refers to the reduction in the capacity to generate maximal force (or torque) induced by exercise (Allen et al., 2008). It is a multi-factorial phenomenon resulting from various factors such as training session characteristics, fitness level, and contraction mode (Koral et al., 2020).This fatigue can be acute or prolonged, leading to muscle weakness (Byrne et al., 2004), decreased strength and reduced muscular power (Allen et al., 2008), impaired motor coordination (Cortes et al., 2014), and diminished sports performance and daily life tasks (Buzzi et al., 2003). It can also contribute to injuries (Meardon et al., 2011).

Neuromuscular fatigue is composed of central (neural) and peripheral (muscular) components. Peripheral fatigue affects motor units, involving mechanical and cellular changes in muscles. On the other hand, central fatigue involves physiological processes in the central nervous system (CNS). While both factors contribute to muscle fatigue, their relative impact varies and isn't fully comprehended by researchers (Wallmann, 2007). Both central and peripheral fatigue occur together, but not in an equal ratio. The kind and style of sports impact how fatigue develops. For instance, in ultra-endurance events, there's more focus on fatigue in the central nervous system compared to shorter athletic activities. Explosive or team sports involve a wide range of factors affecting both the central and peripheral systems (Tornero-Aguilera et al., 2022).

Neuromuscular fatigue occurs in adult athletes (Brownstein et al., 2017; Pinheiro et al., 2022), and also affects children (Akyildiz et al., 2022). Piponnier et al. (2018) showed that peripheral fatigue in children is lower than in adults, while central fatigue is greater in children compared to adults after performing repeated maximum voluntary muscle contractions. Consequently, it is suggested that adults tend to experience higher levels of fatigue than children following extreme physical exertion (Bontemps et al., 2019).Interestingly, children demonstrate a higher resistance to neuromuscular fatigue and exhibit faster recovery rates from bouts of high-intensity physical exertion compared to adults (Falk and Dotan, 2006; Ratel et al., 2006).

Understanding the dynamics of neuromuscular fatigue becomes particularly pertinent in the context of early adolescent athletes engaged in soccer. Limited studies have investigated neuromuscular fatigue in this population. Skala and Zemková (2023) highlighted a substantial decrease in explosive strength, agility, and decision-making abilities immediately following a brief 24-minute 4-side game among early adolescent soccer players. However, to the best of the authors' knowledge, no study has specifically explored the dynamics of neuromuscular fatigue after high-intensity training sessions among this age group. Thus, this study aimed to investigate the impact of a high-intensity training session comprising SAQ drills and SSG games on neuromuscular fatigue levels at specific time points (immediately, one hour, 24 hours, and 48 hours post-session) among early adolescent soccer players.

MATERIAL AND METHODS

Participants
Fourteen amateur male under-14 academy soccer players from Jijel province, Algeria, voluntarily participated in this study. The average age of the players was 13.21 ± 0.69 years, with an average height of 156.28 ± 3.95 cm and weight of 47.14 ± 10.77 kg. On average, they had 2.29 ± 1.74 years of training experience, engaging in 3 to 4 training sessions per week. All participants were screened to ensure freedom from illness, injury, or any health conditions. Before their involvement, the experiment details were explained to the players, their parents, and the coach. Informed consent was obtained from all involved parties. This study adhered to the principles outlined in the Declaration of Helsinki (World Medical Association, 2013).

Design and procedures
This experimental study utilizes a within-subjects, repeated-measures design to assess variations in neuromuscular fatigue among U14 youth soccer players following a sixty-minute training session during the sport season 2022/2023. To ensure sufficient recovery from the prior session, players were granted a two-day rest period before the experiment commenced. Before the training session, participants underwent the CMJ test and the 10-meter sprint test to establish their baseline neuromuscular performance. The study involves data collection at four specific time points: immediately after the training session, at 1 hour post-session, and again at 24 hours and 48 hours post-session (Figure 1). All measurements were conducted at the same time as the usual team's training start time.

In addition, participants were provided with specific guidelines to uphold during the trial period to ensure the accuracy and consistency of the results. They were advised to prioritize obtaining a minimum of 8 hours of sleep each night to ensure adequate rest. Furthermore, participants were encouraged to consume healthy and balanced meals, emphasizing the importance of proper nutrition. To minimize potential confounding factors, participants were instructed to refrain from engaging in any additional physical activities during the trial period. These measures were implemented to mitigate external influences on neuromuscular fatigue and enhance the reliability of the collected data.

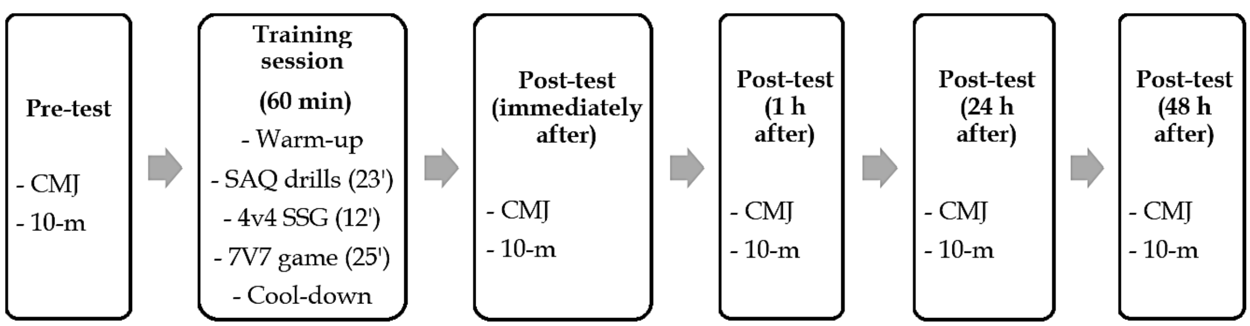

Figure 1. Experimental design.

Neuromuscular fatigue assessment
To assess neuromuscular fatigue in early adolescent soccer players, researchers utilized two well-established field tests represented by the CMJ and the 10-meter speed tests. These tests have been widely used in sports science research and are recognized for their reliability and validity in measuring neuromuscular function and performance changes (Alba-Jiménez et al., 2022).

10 meters test

The test aims to measure the player's acceleration ability within a 10-meter distance. During this test, the player starts running from the starting line and accelerates as quickly as possible toward the finish line. It's noted for its reliability and validity in evaluating speed performance (Altmann et al., 2014). Acceleration, which involves rapid speed development over short distances, heavily depends on the neuromuscular system. Consequently, it serves as a vital indicator for detecting neuromuscular fatigue in athletes (Alba-Jiménez et al., 2022).

Countermovement jump test

This test is easy to use and carries a low risk of injury. Its primary objective is to measure jump height and lower extremity power (Liebermann & Katz, 2003; Quagliarella et al., 2011). It serves as a sensitive tool for monitoring neuromuscular status (Claudino et al., 2017) and fatigue responses (Gathercole et al., 2015).During this test, the player performs a countermovement down to a 90-degree angle at the knee and then executes a jump, keeping the hands placed on the hips to avoid their involvement in the jumping process. The 'My Jump 2 Android application, used on a Samsung A42 phone, was employed to conduct the test. This application is recognized as a valid and reliable tool for measuring CMJ (Vieira et al., 2023). The My Jump 2 app requires two crucial measurements related to the player's leg length. First, the length of the player's leg is measure from the anterior iliac spine to the tip of the boots while the player is in a supine position with their feet fully extended forward. Second, while assuming a 90-degree squatting position, the distance from the anterior iliac spine to the ground is measured.

Training session

The training session was designed considering the principles of sports training and the characteristics of the targeted age group. It commenced with an 8-minute warm-up session, followed by a 10-meter speed and CMJ assessment. The main part of the session incorporated a combination of aerobic and anaerobic exercises, and it began with SAQ exercises integrated with the ball to enhance speed and agility, and passing skills, lasting 10 minutes for two sets, with a 3-minute rest between sets. Each set comprised 10 maximal repetitions. Following a complete 5-minute break, the players engaged in two rounds of a high-intensity 4-side game, each lasting 5 minutes, with a 2-minute rest in between. The field's dimensions for this exercise were set at 15×20 meters. The final exercise involved tactical play and spanned 25 minutes, incorporating a 7v7 game format that included a goalkeeper. The cool-down period consisted of stretching exercises and relaxation techniques, lasting 10 minutes, focusing on flexibility and aiding recovery. The entire session lasted for 60 minutes, characterized by a high-intensity level.

Data analysis

The statistical analysis in this study involved using descriptive statistics such as mean and standard deviation. Following the confirmation of normal data distribution using the Shapiro–Wilk test, parametric procedures were chosen. A one-way ANOVA repeated measures test was then employed to evaluate variations in neuromuscular fatigue across five-time points: baseline, immediately after the training session, 1 hour, 24 hours, and 48 hours post-session. To assess sphericity, Mauchly's test was performed. Subsequently, Bonferroni post-hoc analysis was conducted to examine pairwise comparisons, focusing particularly on baseline comparisons for both tests against subsequent time points. The report encompassed mean differences, 95% confidence intervals, standard errors, effect sizes (Cohen's d), and p-values. The effect sizes indicated practical significance, while the obtained p-values confirmed the statistical significance of observed differences. Effect size values were classified as described by Hopkins et al. (2009), as trivial (<0.20), small (0.20–0.59), moderate (0.60–1.19), large (1.20–2.00), or very large (>2.00).

RESULTS

Table 1. Descriptive statistics.

Tests	Period tests	Mean	SD
10-m (s)	Before the training session	2.27	0.13
	Immediately after	2.31	0.15
	1 hour post-session	2.33	0.17
	24 hours post-session	2.31	0.15
	48 hours post-session	2.28	0.15
CMJ (cm)	Before the training session	30	6.62
	Immediately after	28.42	6.91
	1 hour post-session	25.71	6.99
	24 hours post-session	27.50	6.00
	48 hours post-session	28.57	6.71

Note. CMJ = Counter movement jump; SD = Standard deviation.

Table 2. Post Hoc comparisons - 10-m sprint (s) and CMJ height (cm).

Period tests		95% CI mean difference					
		Mean difference	Lower	Upper	Standard error	Cohen's d	*p*-value
10-m							
Before the training session	Immediately after	-0.039	-0.112	0.035	0.022	0.28	1.000
	1 hour post-session	-0.060	-0.139	0.019	0.023	0.42	.239
	24 hours post-session	-0.039	-0.121	0.044	0.024	0.28	1.000
	48 hours post-session	-0.012	-0.059	0.035	0.014	0.07	1.000
CMJ (cm)							
Before the training session	Immediately after	1.571	-2.248	5.391	1.133	- 0.23	1.000
	1 hour post-session	4.286	0.656	7.916	1.076	- 0.63	.016*
	24 hours post-session	2.500	0.032	4.968	0.732	- 0.37	.046*
	48 hours post-session	1.429	-1.882	4.740	0.982	- 0.21	1.000

*Note. *: p < .05; Cohen's d: effect size; CMJ = Counter movement jump.*

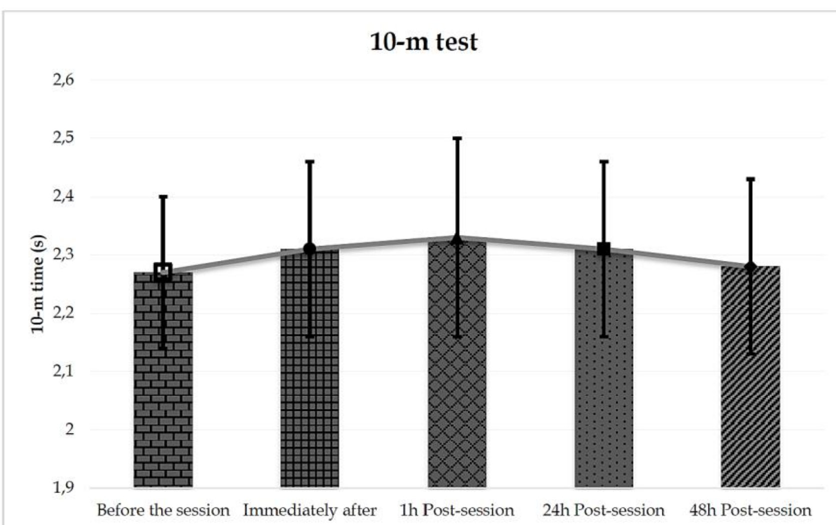

Figure 2. 10 meters test results across different time points discussion.

Tables 1 and 2, as well as Figures 2 and 3, collectively display the results of the statistical analysis of the study's data. Descriptive statistics revealed a change in the mean for both the 10-m sprint test and the CMJ test at various measurement times. When compared to the baseline, there were no statistically significant differences for the 10-m sprint test immediately after the session (*p* > .05, Cohen's d: 0.28), after hour post-session (*p* > .05, Cohen's d: 0.42), after 24 hours (*p* > .05, Cohen's d: 0.0.28), and after 48 hours post-session (*p* > .05, Cohen's d: 0.07).

Regarding the CMJ test, in comparison to the baseline, there were no statistically significant differences in jump height immediately after the session (*p* > .05, Cohen's d: -0.23). However, after one hour and 24 hours post-session, statistically significant differences were observed (*p* < .05, Cohen's d: -0.63; *p* < .05, Cohen's d: -0.37). Additionally, there were no statistically significant differences after 48 hours post-training session (*p* > .05, Cohen's d: -0.21).

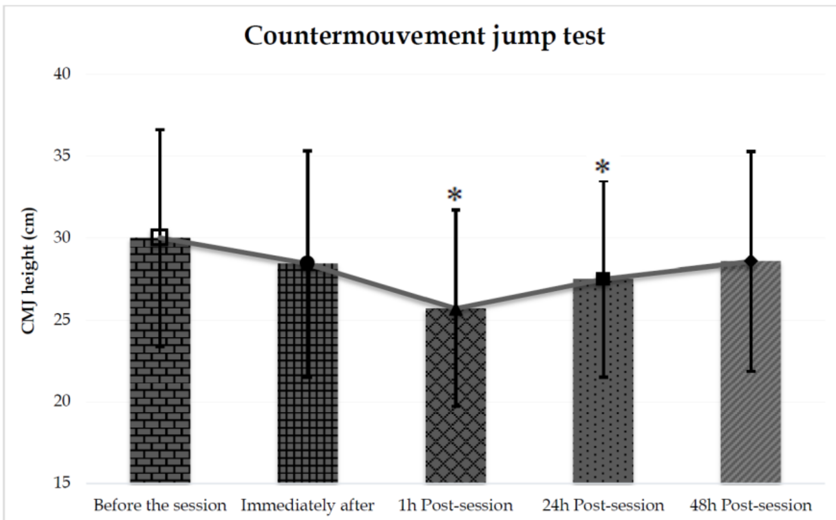

Figure 3. Countermovement jump test results across different time points.

DISCUSSION

The primary aim of this investigation was to explore the impact of high-intensity training on neuromuscular fatigue dynamics among early adolescent soccer players across varying time intervals (immediately after the training session, after 1 hour, after 24 hours, and after 48 hours). The main findings indicated a gradual decline in performance in both CMJ and 10m tests immediately and 1-hour post-training session, followed by a gradual recovery after 24 hours and 48 hours, with statistically significant differences observed in the CMJ test after 1 hour and 24 hours of the training session.

This study provided support for previous research, confirming through its findings that the CMJ test is one of the best and easiest field tests aiding practitioners in evaluating neuromuscular fatigue in their players (Brownstein et al., 2017; Pinheiro et al., 2022; Akyildiz et al., 2022). Conversely, the 10-meter sprint test was not a significant indicator of neuromuscular fatigue. Nevertheless, performance in this test decreased and then approached the initial values after 48 hours, similar to what was observed in the CMJ test, but without any notable statistical differences.

The current study revealed a statistically significant decrease in CMJ performance one hour after the training session, which aligns with the findings of Pinheiro et al. (2022) who observed a similar decrease two hours post-training. The training session involves SAQ drills and SSG games, during which maximal efforts are exerted (Silva et al., 2023), necessitating maximal muscle contractions (Williams et al., 2017). Continuous muscle contractions may result in muscle damage, potentially temporarily impairing players' ability to generate force (Thorlund et al., 2009) and reducing power from the hamstring and gluteal muscles (Small et al., 2010; Edouard et al., 2018). This decline in power can influence the ability to perform rapid movement due to biomechanical issues in the lower limbs (Cortes et al., 2012). This is consistent with what Skala and Zemková (2023) found among football players in early adolescence.

Neuromuscular fatigue persisted after this training session for up to 24 hours. The findings of the current study stand in contrast to previous research. Brownstein et al. (2017) and Akyildiz et al. (2022) observed fatigue persisting for 24 and 48 hours, respectively, after 90-minute matches in 21-year-old and 19-year-old soccer players. Goulart et al. (2022) further affirmed this prolonged fatigue, particularly focusing on female players. Notably, prior studies reported the persistence of neuromuscular fatigue for 24 and 48 hours following intense training involving sprints, jumps, and strength exercises (Thomas et al., 2018; Pinheiro et al., 2022).

These findings underscore the established understanding that children recuperate more rapidly than adults after engaging in high-intensity activities (Falk and Dotan, 2006; Ratel et al., 2006). Interestingly, our study revealed a significant discovery: despite observing no statistical differences between baseline and 48 hours post-session, the CMJ performance did not return to its initial value. This implies potential enduring effects on neuromuscular performance, necessitating further exploration into the prolonged dynamics of post-exercise recovery. Future investigations could concentrate on monitoring neuromuscular fatigue after matches in early adolescent soccer players, potentially involving a larger number of players. Additionally, they could use other accurate measurement methods to monitor neuromuscular fatigue.

CONCLUSION

To the best of the researcher's knowledge, this study is the first to investigate neuromuscular fatigue in U14 early adolescent soccer players. The study's key findings indicated that a high-intensity 60-minute training session led to a significant decrease in CMJ performance for up to 24 hours, approaching the baseline values after 48 hours. Therefore, it can be concluded that neuromuscular fatigue persisted for up to 24 hours. Consequently, the researcher advises youth soccer coaches to ensure adequate recovery time for their players to improve performance and to avoid overtraining and the risk of injury.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

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