

The impact of official soccer matches on the biochemical and neuromuscular performance indicators of elite young players

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Abstract

Soccer is a physically demanding sport, with young players covering total distances of 7,000 to 10,000 m per match. They perform 52 to 100 accelerations and 1,379 to 1,459 activity changes every 4 seconds, requiring up to 72 hours for full recovery. Furthermore, the most critical moments of the game, such as recovering the ball, scoring a goal or making a save, depend on the athlete's ability to perform better in high-intensity movements. The aim of this study was to examine the neuromuscular and biochemical responses of high-level young soccer players to official matches, in order to provide more information about the match impact on the players. Despite the apparent popularity of the subject, there is a lack of scientific evidence on the topic. The sample included 42 male players aged 16–22 years without injury history, divided into an experimental group (n=24) and a control group (n=18). Measurements included neuromuscular performance indices and biochemical markers obtained through blood sampling, conducted 24 hours before and 24 hours after each match. External match load was monitored using a GPS system (Stats, Apex Pro). This protocol was repeated for six matches. Repeated-measures ANOVA was used to analyze changes over time, and paired t-tests analysis. Statistical analysis was performed with SPSS 29, with significance set at $p \leq 0.05$. Results indicated that all measured performance indicators were negatively affected following matches. These findings highlight the multifactorial nature of fatigue in elite young soccer players and underscore the importance of integrated monitoring using biochemical, neuromuscular, and subjective indicators. Organized in-season rehabilitation programs are recommended to facilitate recovery and maintain performance, and further research is suggested to evaluate specific rehabilitation protocols.

Keywords: Recovery, Soccer, Countermovement jump, Muscle damage, Fatigue, Young players, In-season.

Introduction

Apart from being a physically demanding process, match play places a considerable burden on players, with research showing that professional soccer players at the European level compete, on average, once every 4.3 days, including travel time (Kellmann, 2002). Over the course of an entire season, teams may participate in more than 60 matches. Consequently, professional soccer players may experience prolonged fatigue throughout the season - particularly during periods of fixture congestion - which can negatively affect subsequent performance and increase the risk of injury (Carling, Le Gall, & Dupont, 2012).

All sport-specific activities performed during a match contribute to the fatigue observed in players afterward. The high mechanical loads experienced during competition can induce significant fatigue (Robineau et al., 2012), muscle damage (Ascensão et al., 2011), and reductions in neuromuscular function (Ascensão et al., 2011; Robineau et al., 2012). In addition, performance factors such as maximal strength, repeated-sprint ability, jumping ability, and sprint performance have been shown to decrease immediately after a match, with full recovery taking up to 72 hours (Ispirlidis et al., 2008; Krstrup et al., 2006).

In team sports such as soccer, a player's motor behavior—both physical and tactical—is shaped by interactions between the player, the game, and environmental constraints (Newell, 1986). Consequently, performance in team sports depends on the ability of players to identify relevant environmental cues and exploit opportunities for action (Travassos, Gonçalves, Marcelino, Monteiro, & Sampaio, 2014).

Based on these considerations, it is likely that both the physical and tactical behavior of players are influenced during periods of muscular and/or central fatigue. Previous studies have shown that changes in physical performance occur during soccer matches (Rampinini et al., 2011), which cannot be attributed solely to team strategy or playing position (Castellano, Blanco-Villaseñor, & Alvarez, 2011), but may also result from

muscle fatigue (Bishop, 2012; Nédélec et al., 2012; Tomazin, Morin, & Millet, 2016). The demands of soccer matches (Bush, Barnes, Archer, Hogg, & Bradley, 2015), and particularly the high-intensity actions, lead to transient muscle fatigue (Silva et al., 2017), which affects players' activity profiles.

Therefore, one of the main challenges for coaches is to achieve an optimal balance between match-induced stress and recovery (Soligard et al., 2016; Schweltnus et al., 2016). To achieve this balance, it is essential to first understand how an official soccer match affects players' fatigue status. Exercise scientists often use multiple biomarkers to monitor recovery processes in soccer (Marqués-Jiménez et al., 2016). Biomarkers should be considered complementary to information obtained from physical performance and perceptual measures (Marqués-Jiménez et al., 2016, 2017). Additionally, neuromuscular fatigue can be evaluated with valid and reliable tests such as the countermovement jump (CMJ) test (Claudino et al., 2017; Garrett et al., 2020; Marrier et al., 2017; Markovic et al., 2004) and the 20-meter sprint test (Twist et al., 2013).

The assessment of an athlete's fatigue is a multifactorial process that should include biochemical, neuromuscular, and subjective indicators, consistently monitored throughout the season.

Material & Methods

Participants

The research sample consisted of 42 young professional soccer players (n=18 Superleague u19, n=24 Superleague 2), aged 16 to 22 years without injury problems, height 178.61 ± 6.47 cm, body weight 71.3 ± 6.3 kg. Eighteen were the control group and twenty-four were the experimental group. Those who did not play the entire official match, as well as goalkeepers, were excluded from the study.

Materials

The anthropometric characteristics height and body weight were recorded using a stadiometer (Seca 222, Hamburg, Germany) and a calibrated bascule (Seca 634, Hamburg, Germany).

Photocells

Two pairs of photocells (Autonics, BX5M – MFR – T)), consisting of two beams, each with two pairs of photocells and an automatic digital timer (Saint Wien Digital Timer Type H5K), with minimum time measurement, measurement error ± 0 , were used to measure the agility ,01sec.

Isokinetic test

An isokinetic dynamometer type Biodex 3 (Biorex, Biotex Corporation, Shirley NY, USA) with which we recorded the peak torque at predetermined constant angular velocities.

Jump test

An OptoJump system (Optojump, Microgate, Bolzano, Italy) which consists of two rods, one of which acts as a transmitter unit containing 96 light-emitting diodes placed 0.003m above the ground, while the other acts as a receiver unit.

Blood test

Blood collection vials and syringe.

Procedure

All procedures were carried out during in season, before and after of six official matches, of the second professional division of Greece (Superleague2). The process of recording the data during the execution of the tests was carried out in two different time periods for each match 24 hours before the match whose data formed the basis, 24 hours after the match data which reflects the effect the burden of the match, as the external load of the match was recorded with a short-range telemetry system and a three-axis accelerometer integrated into the GPS. A standard warm-up was conducted after blood sampling and before performance tests. The warm-up consisted of 6 minutes of easy treadmill running, dynamic stretching and coordination exercises. All measurements were performed at the same time of day to avoid circadian variation.

Anthropometrical

Height(m) and body weight(kg) were measured at the beginning of the first testing session. A stadiometer (Seca 222, Hamburg, Germany) and a calibrated bascule (Seca 634, Hamburg, Germany) were used for that purpose.

Biochemical markers

Blood sample

Before the remaining tests, blood was drawn to assess seven biochemical markers. Blood would be collected into 2 different empty blood collection tubes. The blood was boiled at room temperature for 30-45 minutes. The analysis process was carried out in collaboration with an accredited biochemical laboratory.

Neuromuscular markers

Max strength

The participants after the warm-up performed on the isokinetic dynamometer with their dominant leg 5 attempts (3 warm-up attempts and 2 maximal) in a full range of knee flexion-extension. Players were tested in a seated position with a hip angle of 100° . Fixation straps were used to secure the pelvis and thigh of the test leg. The shoulders were fixed with shoulder pads in the ventral-dorsal and cranio-caudal directions.

The axis of rotation of the dynamometer was aligned with the axis of rotation of the knee (lateral femoral epicondyle). The lever arm of the dynamometer was attached to the distal part of the tibia, and the lower end of the tibial pad was placed ≈ 2 cm above the medial malleolus.

Static gravity correction was applied according to the manufacturer's instructions. Test range of motion was 80° and defined from 10° to 90° of knee flexion (with 0° = full voluntary extension). Soccer players were asked to kick and also flex the tested leg as hard and as fast as they could through a full range of motion (from 90° to 0°).

Jump test

Participant's neuromuscular fatigue was determined using the Counter Movement Jump (CMJ) test. The CMJ test is valid and reliable (Claudino et al., 2017; Garrett et al., 2020; Marrier et al., 2017; Markovic et al., 2004). The soccer players after the warm-up performed 3 CMJ attempts on the OptoJump system, with the hands on the medial and with the prompt to jump as high as possible. Finally, the best of the 3 attempts was chosen.

Speed test

Sprint evaluation was accomplished through a speed test that was carried out in a straight 20 m line. Sprint times (s) were measured by two pairs of photocells (Autonics, BX5M – MFR – T) in the beginning and in the end of the 20m line. The athletes started in the same line of first pair of photocells in order to ensure that their initial speed was zero. The players performed 2 trials with a 3 min recovery period between. The fastest result was recorded for further analysis.

External load record

External load loads from each match were recorded using a short-range telemetry system and GPS-integrated triaxial accelerometer (Stats, Apex pro). The soccer players wore personalized gps during all official matches. External load measurements recorded were total distance in meters (TDm), high speed runs (HSRm) ≥ 19.8 km/h, high metabolic load distance (HMLDm), sprint distance (SPRINT D. m) ≥ 25 km/h, strong accelerations (ACC) $\geq 3\text{m/s}^2$ and strong decelerations (DEC) $\geq 3\text{m/s}^2$.

The data was downloaded to a computer and processed by the special program of Stats (Sonra) to avoid noises and to ensure that only the match is recorded (Table 1).

Table 1. External load match data

TEAM AVG	TD(m)	HSR(m)	HMLD(m)	SPRIND D.(m)	ACC(m)	DECC(m)
MATCH 1	10658	612	1930	77	83	88
MATCH 2	10155	556	1793	88	75	87
MATCH 3	9574	521	1737	84	62	71
MATCH 4	10002	589	1867	90	65	76
MATCH 5	10459	650	1927	71	60	79
MATCH 6	9968	510	1698	64	58	65

Statistical analysis

Repeated-measures ANOVA was used to analyze changes over time, and paired t-tests analysis. Statistical analysis was performed with SPSS 29, with significance set at $p \leq 0.05$.

Results

Biochemical and neuromuscular responses to official soccer matches are presented for the experimental and control groups. In the experimental group, creatine kinase increased from 492.96 ± 212.41 to $1,215.17 \pm 405.52$ U/L, $p = .001$ (Fig.1), urea from 36.02 ± 4.64 to 39.46 ± 4.91 mmol/L, $p = .023$ (Fig.2), uric acid from 4.82 ± 0.62 to 5.11 ± 0.90 mg/dL, $p = .003$ (Fig.3) and WBC from $5,326.67 \pm 1,215.81$ to $5,992.92 \pm 1,439.88$, $p = .001$ (Fig.4), whereas cortisol decreased from 14.95 ± 2.39 to 11.50 ± 3.23 $\mu\text{g/dL}$, $p = .001$ (Fig.5). Free testosterone decreased slightly from 22.23 ± 5.47 to 20.43 ± 4.51 , $p = .068$ (Fig.6), and LDH increased from 415.25 ± 70.45 to 581.63 ± 178.83 , $p = .001$ (Fig.7).

The control group showed minimal changes in all biochemical markers. Neuromuscular performance in the experimental group declined post-match, with CMJ height decreasing from 42.56 ± 2.38 to 39.47 ± 2.41 cm, $p = .001$ (Fig.8), 20 m sprint time increasing from 3.02 ± 0.07 to 3.25 ± 0.57 s, $p = .049$ (Fig.9), knee extension peak torque decreasing from 311.67 ± 22.12 to 272.73 ± 31.41 Nm, $p = .001$ (Fig.10), and knee flexion peak torque from 197.67 ± 16.51 to 177.73 ± 25.90 Nm, $p = .001$ (Fig.11).

The control group remained stable in all neuromuscular measures. These results indicate clear post-match elevations in biochemical markers of muscle damage and metabolic stress, along with declines in neuromuscular performance in the experimental group, while the control group exhibited negligible changes (Table 2).

Table 2. Mean and Standard deviation of the variables

Experimental Group	Mean	Std. D	Control group	Mean	Std. D
CK pre	492.96	212.41	CK pre	578.03	61.28
CK post	1215.17	405.52	CK post	587.22	55.07
UREA pre	36.02	4.64	UREA pre	38.14	6.27
UREA2 post	39.46	4.91	UREA2 post	36.63	6.22
UREA ACID pre	4.82	0.62	UREA ACID pre	4.56	0.63
UREA ACID post	5.11	0.90	UREA ACID post	4.71	0.75
WBC pre	5326.67	1215.81	WBC pre	4915.00	827.28
WBC post	5992.92	1439.88	WBC post	4513.33	1114.39
COR pre	14.95	2.39	COR pre	14.32	4.69
COR post	11.50	3.23	COR post	14.35	4.68
FREE-TEST pre	22.23	5.47	FREE-TEST pre	26.75	9.45
FREE-TEST post	20.43	4.51	FREE-TEST post	26.80	9.48
LDH pre	415.25	70.45	LDH pre	460.42	190.97
LDH post	581.63	178.83	LDH post	460.76	191.50
cmj pre	42.56	2.38	cmj pre	43.17	7.76
cmj post	39.47	2.41	cmj post	43.37	7.76
20m-sprint test pre	3.02	0.07	20m-sprint test pre	3.03	0.20
20m-sprint test post	3.25	0.57	20m-sprint test post	2.82	0.48
Peak torque ext pre	311.67	22.12	Peak torque ext pre	312.83	78.28
Peak torque ext post	272.73	31.41	Peak torque ext post	313.80	78.42
Peak torque flex pre	197.67	16.51	Peak torque flex pre	272.47	353.03
Peak torque flex post	177.73	25.90	Peak torque flex post	190.89	43.47

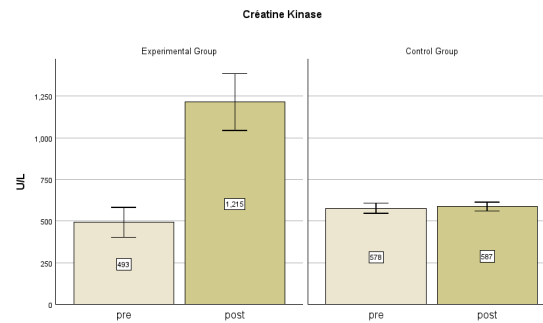


Figure 1: Creatine Kinase (Mean±SD, $p \leq 0.05$)

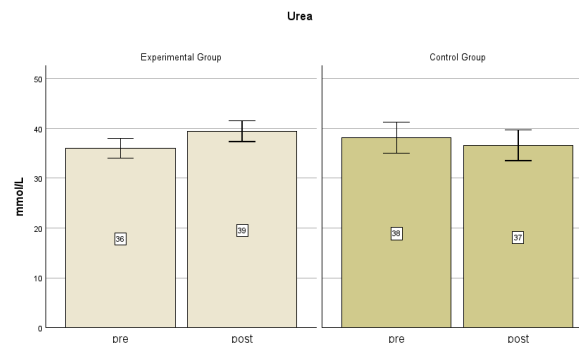


Figure 2: Urea (Mean±SD, $p \leq 0.05$)

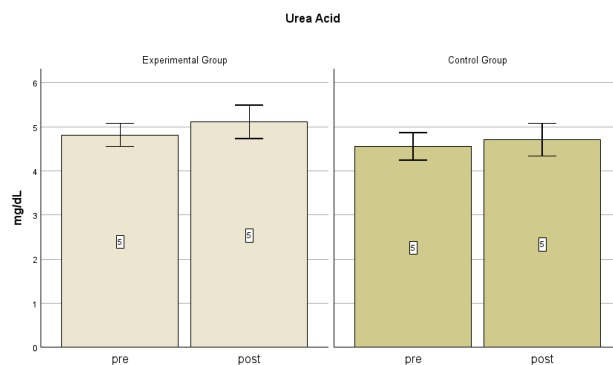


Figure 3: Urea Acid (Mean±SD, $p \leq 0.05$)

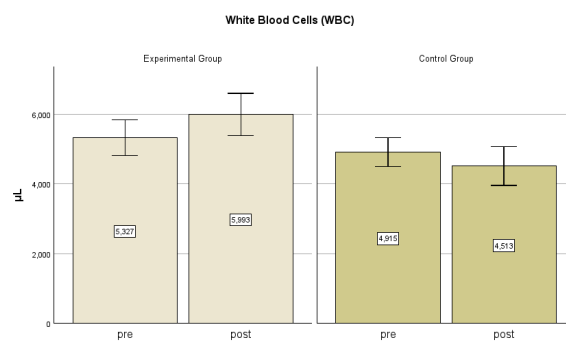


Figure 4: White Blood Cells (Mean±SD, $p \leq 0.05$)

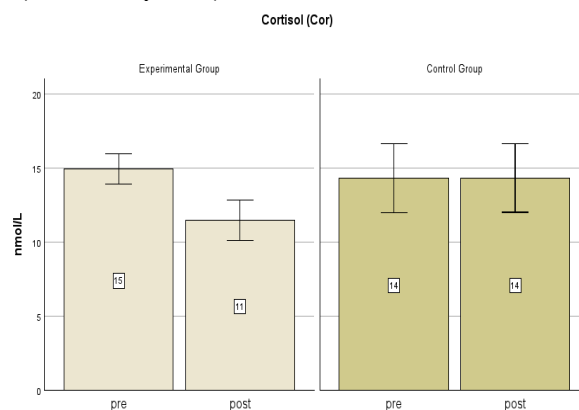


Figure 5: Cortisol (Mean±SD, $p \leq 0.05$)

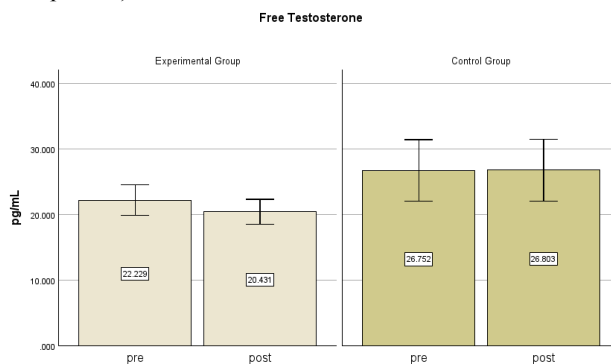


Figure 6: Free Testosterone (Mean±SD, $p \geq 0.05$)

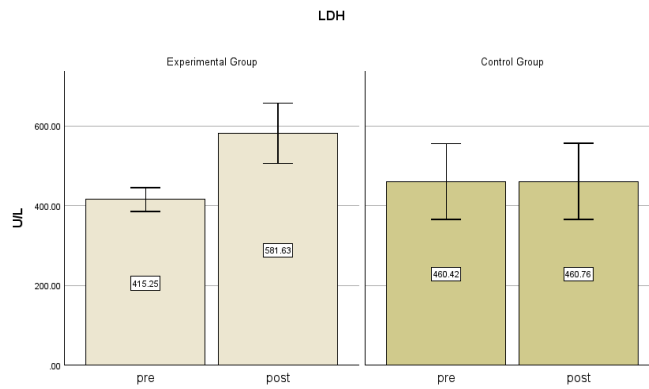


Figure 7: LDH (Mean±SD, $p \leq 0.05$)

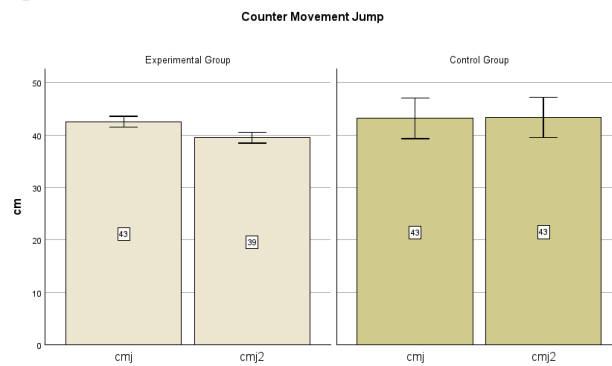


Figure 8: Counter Movement Jump (Mean±SD, $p \leq 0.05$)

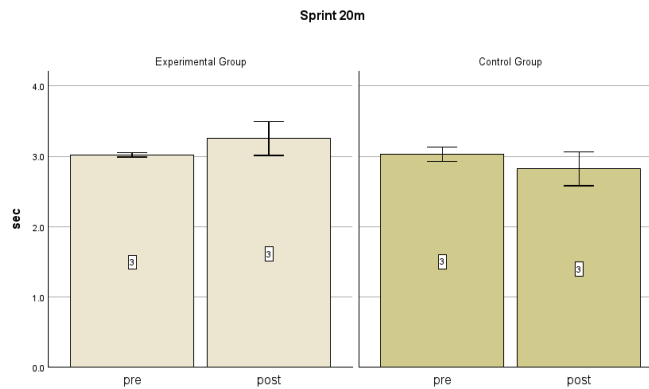


Figure 9: 20m Sprint (Mean±SD, $p \leq 0.05$)

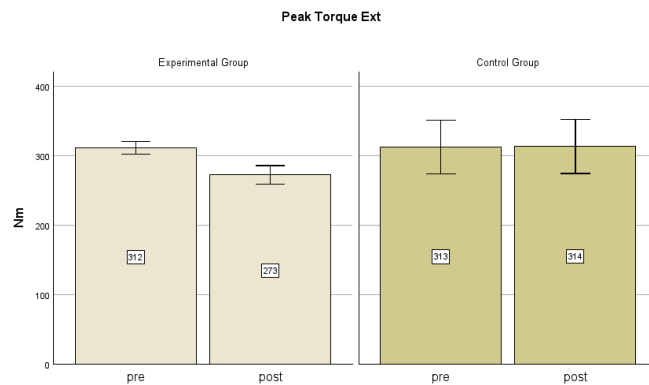


Figure 10: Peak Torque Ext (Mean±SD, $p \leq 0.05$)

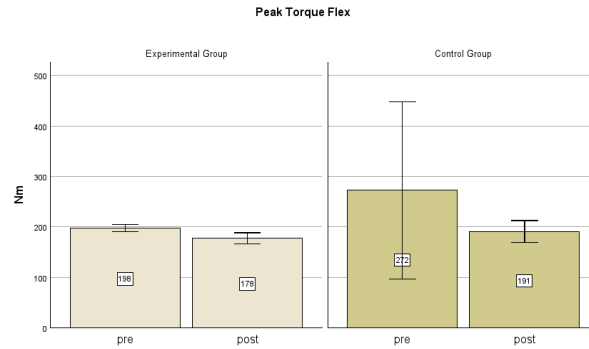


Figure 11: Peak Torque Flex (Mean±SD, $p \leq 0.05$)

Discussion

Considering the complexity of assessing fatigue, a multidimensional approach that integrates various parameters - neuromuscular, biochemical, and subjective - is recommended (Marques-Jimenez et al., 2017). The present study demonstrates that an official soccer match induces significant fatigue, as evidenced by notable changes in both biochemical and neuromuscular markers.

Regarding biochemical responses, a 40.06% increase in lactate dehydrogenase (LDH) was observed, indicating that this variable was significantly affected by the match. This finding is consistent with previous research reporting post-match LDH elevation following soccer and rugby activities (Mashiko et al., 2004; Takahashi et al., 2007; Trajkovic et al., 2018). Creatine kinase (CK) levels also showed a statistically significant increase of 146.5%, confirming substantial muscle damage or stress. Similar CK elevations have been reported immediately after competitive play or football simulation tests (Andersson et al., 2008), with peak values typically occurring approximately 24 hours post-match (Rampinini et al., 2011; Silva et al., 2013; Bouzid et al., 2019; Wiig et al., 2022), likely due to delayed enzyme clearance (Hyatt & Clarkson, 1998). Furthermore, during congested match schedules, CK concentrations are higher, as demonstrated by Garcia-Romero-Perez et al. (2021), who found elevated pre-match CK levels among players with greater playing time.

Uric acid concentration increased by 6.18%, consistent with previous findings indicating that intense exercise enhances purine metabolism and muscle membrane disruption (Palacios et al., 2015; Nidhal et al., 2023). Similarly, blood urea rose significantly by 9.54%, suggesting elevated protein catabolism and metabolic stress. These results align with studies showing increased urea levels after high-intensity exercise (Palacios et al., 2015), reinforcing its role as a useful indicator of training load, energy substrate utilization, and potential overtraining risk. White blood cell (WBC) count also increased by 12.5%, reflecting an acute inflammatory response or incomplete recovery (Shek et al., 1995). This hematological response has been previously observed in soccer players as a short-term reaction to match-induced stress (Anđelković et al., 2015; Mohr et al., 2016; Farjallah et al., 2020). No significant changes were observed in free testosterone, indicating a potentially blunted or variable hormonal response among young elite players. In contrast, cortisol levels decreased by 23.1%, consistent with a return toward baseline and the resolution of acute stress following match completion.

Neuromuscular performance also showed significant decrements. Countermovement jump (CMJ) height decreased by 7.26%, indicating neuromuscular fatigue (Andersson et al., 2008; Claudino et al., 2017; Akyilzi et al., 2022). This reduction aligns with Nedelec et al. (2014), who reported impaired CMJ performance lasting up to 72 hours post-match, reflecting the involvement of the stretch-shortening cycle (Nicol et al., 2006). Sprint performance declined, with 20 m sprint time increasing by 7.62%, comparable to findings by Ascensao et al. (2008) but slightly higher than those of Ispirlidis et al. (2008) and Knist et al. (2006). Variability in player characteristics likely explains these differences. Additionally, maximal isokinetic torque for both knee flexion and extension decreased by 10.08% and 12.49%, respectively, corroborating earlier reports in elite male (Raastad et al., 2002) and female players (Andersson et al., 2008). Such reductions may result from structural muscle fiber disturbances caused by repeated high-force actions during gameplay (Gibala et al., 1995; Raastad et al., 2000). Taken together, the observed alterations in biochemical and neuromuscular parameters confirm that an official soccer match induces acute, multidimensional fatigue in young elite players. These findings emphasize the importance of integrated fatigue monitoring combining biochemical and performance-based indicators to optimize recovery strategies and manage player readiness effectively.

Conclusion

The present study confirms that participation in an official soccer match induces acute and multidimensional fatigue in young elite players. Significant changes in both biochemical and neuromuscular markers highlight the considerable muscular and metabolic strain imposed by competitive play. Prolonged exposure to frequent matches can result in cumulative fatigue, negatively affecting subsequent performance and increasing the risk of injury (Carling et al., 2012).

Given the multifactorial nature of fatigue, its assessment should integrate biochemical, neuromuscular, and subjective indicators that are consistently monitored throughout the season. Developing individualized fatigue profiles for each player can provide valuable insights into recovery status and readiness, supporting data-driven decision-making in training and match scheduling.

Implementing structured recovery and rehabilitation programs is strongly recommended to ensure effective restoration of performance capacities and to minimize potential injury risks. Overall, a multidimensional and personalized monitoring approach appears essential for optimizing player management, enhancing performance, and promoting long-term athletic health in elite soccer environments.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors didn't use of AI in the writing of the article.

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