Monitoring the post-match neuromuscular fatigue of young Turkish football players

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Neuromuscular fatigue tests have been used in previous studies to organize post-match training programs and to minimize injuries. The aim of this study is to describe the neuromuscular fatigue that occurs after a football match and to examine the relationship between internal and external load values in the match and fatigue parameters obtained at different time intervals. Twenty male U19 academy league soccer players (age: 19; height: 181.3 ± 4.3; weight: 73.4 ± 6.7) participated in the study. The countermovement jump (CMJ) test was applied to the players 24 h before, as well as 24, 48, 72, 96, and 120 h after a football match. During the CMJ tests, the maximum velocity of each player during the jump was recorded by using the GymAware linear position transducer. The CMJ maximum velocity values 24 h before and 24 h after the match, as well as the CMJ height values (Cohen’s d: 1.210; p < 0.001), were statistically different from the values recorded 24 h before and 24 and 48 h after the match (Cohen’s d: 1.578; p < 0.001; Cohen’s d: 0.922; p < 0.009). The correlation values were not statistically significant. The results suggest, CMJ height and CMJ maximum velocity values, which determine neuromuscular fatigue after a football match, can be used by practitioners to display post-match neuromuscular fatigue measurements.

Football is considered a high-intensity interval sport with an unprecedented increase in high impulsive actions occurring during match play observed over the past decade1. Football players today experience an increase in the physical demands of matches due to short recovery times between matches and high neuromuscular demands2. Increasing demands in match and congested fixtures can cause temporary fatigue during matches3,4. Increased performance needs and recovery problems mean longer times are needed to fully recover5,6.

After eliminating the fatigue of a match played on the weekend, detailed plans need to be formed regarding the technical, tactical, and physical deficiencies of players via training until the next match is played the next weekend and; at the same time, players must be made ready for the next match with the most appropriate performance7. In some cases, there is not even a week’s recovery period between games. Teams are exposed to fatigue due to congested fixtures and the team’s playing in different leagues3,4. For this reason, observing neuromuscular fatigue in players is crucial for sports scientists and trainers to organize their weekly training programs correctly and to protect players from injuries7,8.

Neuromuscular fatigue has been defined as any exercise-induced reduction in maximal voluntary force or strength produced by a muscle or muscle group in humans9,10. Traditionally, neuromuscular fatigue has been studied using isolated forms of isometric, concentric, and eccentric movements9. However, recent evidence suggests that combining movements involving the stretch–shortening cycle (SSC) enables a more in-depth specific investigation of neuromuscular fatigue11–13. Movements involving SSC include metabolic, mechanical, and neural components of fatigue with impaired yawn reflex activation13. SSC involves a pre-activated muscle that is commonly used when one performs activities involving different stages of running or jumping, which is stretched first and then shortened12. Recovery after impaired SSC function takes place in two stages: (a) a significant reduction

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The countermovement jump (CMJ) test is widely used among soccer players and team leaders to measure neuromuscular fatigue. CMJ decreases in direct proportion to decreases in SSC, thus reflecting neuromuscular fatigue. In addition, the validity and sensitivity of the CMJ test are high, and it is potentially practical for detecting and measuring fatigue in field conditions. Further, many studies have found that CMJ testing reflects neuromuscular fatigue. Several studies have used CMJ tests to measure neuromuscular fatigue among football players. In these studies, neuromuscular fatigue after matches was examined using the CMJ test.

A better understanding of neuromuscular responses to soccer matches can improve individualized post-match strategies, reduce the risk of residual and cumulative fatigue, and reduce the rate of musculoskeletal injury. The current research systematically examined the time course of players' neuromuscular responses at different time intervals before and after a football match. At the same time, this research examined the relationship between the internal and external training load values during the match and the changes in the fatigue variables according to time.

Therefore, the aims of this study are to examine the differences in the neuromuscular fatigue of football players 24, 48, 72, 96, and 120 h after a match and to investigate the relationship between internal and external training load values during a match and temporal changes in fatigue parameters. The findings of this study provide practical information to sports scientists and coaches about the training programs and recovery protocols of players.

The findings of this study provide new information to researchers and practitioners by revealing differences in CMJ height and CMJ maximum velocity values, which are used to detect neuromuscular fatigue after a football match, and by investigating the relationship between internal and external training load variables during a match.

**Methods**

**Experimental approach to the problem.** An experimental study was carried out among the players of a football team. The study examined the neuromuscular fatigue that occurs in players during matches at different time intervals, as well as the relationship between internal and external training load variables in matches and neuromuscular fatigue at different times. The study was designed during a normal match period week in the 2020/2021 season. The tests were carried out during the regular match period of the season. All matches in the study were conducted under normal field conditions. The purposes of the study were to examine the differences between the pre-match baseline values and the post-match values at 24, 48, 72, 96, and 120 h, as well as to investigate the relationships between internal and external load demands and fatigue values during matches.

In the session 24 h before the match day, the height and weight of each athlete were measured. After the anthropometric measurements were taken, the players performed three CMJ repetitions. On the day of the match, the players were made to jump three times during the CMJ test. Immediately after the test, the players participated in a friendly match consisting of 90-min (2 × 45 min) periods and played under official field conditions.

During the match, the players' heart rate, accelerations, and distance traveled were measured with the help of Polar Pro Team GPS (Finland). The CMJ height, and CMJ maximum velocity values obtained from the CMJ tests at the 24th hour, 48th hour, 72th hour, 96th hour, and 120th hour after the match were recorded. The total length of this study was one week. The structure of the experimental study protocol is shown in Fig. 1.

**Participants.** Twenty football players (age: 19; height: 181.3 ± 4.3; body mass: 73.4 ± 6.7) who played in the U19 Academy League voluntarily participated in the study. The criteria for inclusion in the study were at least 3 years of football history and no injury. Players who did not have a football background for 3 years, participated in heavy exercise before the tests and had any injuries were excluded from the tests in the study. 20 people participated in the study and all participants met the participation criteria. All participants consisted of football players who train regularly (5 days a week/1.5–2 h). All 20 participants performed the tests as part of the normal training program week and were familiar with the pre-study procedures.

24 h before the match. Neuromuscular fatigue measurements.

24 hours after the match. Neuromuscular fatigue measurements.

48 hours after the match. Neuromuscular fatigue measurements.

72 hours after the match. Neuromuscular fatigue measurements.

96 hours after the match. Neuromuscular fatigue measurements.

120 hours after the match. Neuromuscular fatigue measurements.
Countermovement jump tests. The neuromuscular fatigue of the participants was determined using the
countermovement jump (CMJ) test. Research reports that the CMJ test is a valid and reliable\(^{16,20,22,31}\). CMJ measure-
ments were conducted prior to the training session. Players participated in a 10-min standardized warm-
up prior to the test. This warm-up consisted of various dynamic movements and running-based exercises of
increasing intensity. This warm-up included two sets of following movements or exercises: Straight ahead, Hip
Out, Hip in, circling partner, Shoulder contact, across the pitch, Bounding.

Lower leg stretches, upper body stretches, mobilization exercises, and stabilization exercises were performed
before CMJ measurements were taken (directed by one of the researchers). Moreover, the participants performed
three submaximal CMJ trials for familiarization before each CMJ measurement. CMJ testing was performed
using previously used protocols\(^{32}\). Participants stood upright with the bar over their shoulders and applied
pressure to prevent the bar from moving independently of their body. They were asked to jump as high as possible
in a fluid movement.

According to previous studies, the test involved participants jumping as high as possible for each trial with a
400-g bar positioned on their shoulders along a horizontal plane. Similar to previous procedures\(^{22,32,33}\), subjects
were encouraged to self-select the CMJ tension or rate with no attempt to standardize.

The participants were instructed not to pull their knees toward their bodies during the jumping phase. They
were also instructed to stretch their legs and land with their legs straight during the flight phase. The participants
performed three jumps, and jump performance was observed by the researcher. Recovery time between jumps
was 2–3 min\(^{32}\). Any jump that was not performed following the proper technique was repeated. The best score
(jump height) of the three jumps was recorded for evaluation.

As in previous research\(^{20,22,33,34}\), CMJ height and CMJ maximum velocity were used as the main criterion
measures for neuromuscular fatigue. Device fixed to the floor during CMJ measurements and connected to the
400-g rod with a cable to be analyzed through an optical encoder (GymAware Power Tool, Kinetic Performance
Technologies, Canberra, Australia). The players performed all CMJ tests between 17:00 and 17:15 in the after-
noon. All testing sessions took place at the same time of day for each participant (± 15 min) and under similar
environmental conditions (± 23°C ± 4°C and ± 60% ± 5% humidity).

Match load monitoring. A friendly match was played for the players in official field conditions, with a
15-min rest between the two 45-min halves. During the friendly match, the players’ heart rate, acceleration
and distance were measured with the help of 10 Hz Polar Pro Team GPS (Polar Electro, Kempele, Finland). The
internal and external load parameters obtained from the players during the match are as follows: External load
variables: 00–13.99 km/h, 14–19.99 km/h and > 20 km/h (m), > 3 m/s \(\#\) Acc (N) values\(^{35,36}\), Internal load vari-
ables: % HRmax 50–59, % HRmax 60–69, % HRmax 70–79, % HRmax 80–89, % HRmax 90–100 (min). It was
ensured that the players played in the same tactical formation (4–4–2) in both halves of the match.

Statistical analysis. Standard deviation and mean values for all parameters were reported. The normal
distribution, Kolmogorov–Smirnov and homogeneity of all data obtained from the tests were tested by looking
at the “skewness” and “kurtosis” values. The significance of temporal changes of fatigue measurements made
at different hours was investigated by applying post hoc analysis of variance in repeated measurements.
The effect sizes of the differences between the tests are shown by Cohen’s d value. The effect size of the differences
of the tests was determined as Cohen’s d, which was considered as 0–0.19 insignificant, 0.2–0.59 small, 0.6–1.19
medium, 1.20–1.99 large, 2.00–3.99 very large, and d > 4 excess\(^{37}\). Pearson analysis was chosen as the relation-
ship since the data were normally distributed. As the level of the relationship: Minor (0.0), small (0.1), medium
(0.3), large (0.5), very large (0.7), almost perfect (0.9) and perfect (1.0) levels were used. An alpha level of \(p < 0.05\)
determined as the significance level\(^{37}\). All statistical analysis and graphs were made using R studio version
1.3.1093.

Ethics approval and consent to participate. The study fully adheres to the ethical principles of the
declaration of Helsinki as well as GCP guidelines. The study was approved by the Research Ethics Committee
of Afyon Kocatepe University (Number: Dated 19.01.2021, numbered 26.01.2021-3764). Informed consent was
obtained from all subjects agreed to participate in this study and answered the questionnaire.

Results

Descriptive values for CMJ test are given in detail in Table 1. Table 2 shows the CMJ maximum velocity (m/s)
and CMJ height velocity temporal variations. There was a statistically significant difference between the test 24
hours before and the test after 24 h (\(p > 0.001\), Cohen d; 1.210); 24 h before and the test after 24 h (\(p > 0.001\), Cohen d;
1.578); 24 h before and the test after 48 h (\(p > 0.01\), Cohen d; 0.922).

Figure 2 shows the individual CMJ maximum velocity (m/s) values of the players at different measurement
times. Figure 3 shows the individual CMJ height (cm) values of the players at different measurement times.

In Fig. 4, the total distances covered by all players in the match, 0–13.99 km/h, 14–19.99 km/h and > 20 km/h
and \(\#\) Acc (N) values of all players > 3 m/s are shown (m). In Fig. 5, the time (min) spent by all players during the
match in % Heartrate (HR) max 50–59, % HRmax 60–69, % HRmax 70–79, % HRmax 80–89, % HRmax 90–100.

Tables 3, 4, 5 and 6 show the relationship between the neuromuscular fatigue responses of the players at dif-
ferent times and the internal and external loads obtained from the match. As a result of the correlation analysis,
no statistical relationship was found between any values.

Discussion

In this study, the neuromuscular fatigue imposed on players after a football match was examined.
The results indicate a statistically significant difference between the test 24 h before and the test after 24 h (p > 0.001, Cohen d; 1.210); 24 h before and the test after 24 h (p > 0.001, Cohen d; 1.578); 24 h before and the test after 48 h (p > 0.01, Cohen d; 0.922).

The correlation analysis presents no statistical correlations between the internal and external load values obtained from the matches and the neuromuscular fatigue values measured at different time intervals.

Activities that occur within football matches cause fatigue in the players\(^3\)\(^8\). The fatigue variables triggered by matches directly affect the structure of the training program during the next days, as well as the match to be held the following week\(^1\)\(^5\). The fatigue of the athletes is controlled during the trainings and it is ensured that they play the matches in a recovered way\(^1\)\(^5\),\(^3\)\(^8\),\(^3\)\(^9\). The effective control of fatigue is provided by sports scientists, coaches, or strength conditioning coaches\(^4\)\(^0\). Keeping fatigue under control and promoting optimum performance from players are related to the ability to balance fatigue, nutrition and rest\(^1\)\(^5\),\(^4\)\(^0\). The balance of the fatigue-resting mechanism in football teams is carried out by individuals responsible for monitoring the training load and fatigue of the team\(^4\)\(^0\),\(^4\)\(^1\).

The fatigue that occurs in the players during training and matches is evaluated under two different load types\(^1\)\(^5\),\(^4\)\(^0\),\(^4\)\(^2\),\(^4\)\(^3\). Physiological stressors that occur in players during training and matches are called internal load\(^1\)\(^5\),\(^4\)\(^0\),\(^4\)\(^2\),\(^4\)\(^3\). Kinematic activities that create physiological stressors are also called external loads. In our study, heart rate variables are called internal load, and distances covered are called external load\(^1\)\(^5\),\(^4\)\(^0\),\(^4\)\(^2\),\(^4\)\(^3\).

It is of vital importance for the players that these individuals determine how much fatigue occurs during training and matches and take appropriate action\(^3\)\(^5\). The main problem addressed in our study is related to temporal changes in neuromuscular fatigue during the week, which were determined by measuring neuromuscular fatigue that occurs after the match through CMJ tests performed at different times.

Decreased neuromuscular performance capacity is generally reported to be associated with muscle fatigue\(^4\)\(^0\),\(^4\)\(^2\). In previous studies, significant decreases in CMJ performance were observed after football matches\(^4\)\(^0\),\(^4\)\(^2\). Studies measuring the height of the CMJ test have reported that jump height decreases with fatigue\(^2\)\(^4\),\(^2\)\(^8\),\(^3\)\(^8\),\(^4\)\(^6\). Prolonged and repetitive exercises affect the SSC and may reduce CMJ performance in this case\(^2\)\(^8\),\(^3\)\(^8\),\(^3\)\(^8\),\(^4\)\(^4\). Studies that have investigated the performance of SSC on neuromuscular fatigue in more detail show changes in

| Table 1. Descriptive statistics. |
|---------------------------------|
| **Period tests** | **Mean** | **SD** |
| After 120 h CMJ Maximum velocity (m/s) | 3.21 | 0.343 |
| After 24 h CMJ maximum velocity (m/s) | 2.76 | 0.402 |
| Before 24 h CMJ maximum velocity (m/s) | 3.08 | 0.366 |
| After 48 h CMJ maximum velocity (m/s) | 3.06 | 0.353 |
| After 72 h CMJ maximum velocity (m/s) | 3.07 | 0.345 |
| After 96 h CMJ maximum velocity (m/s) | 3.17 | 0.436 |
| After 120 h CMJ height (cm) | 36.2 | 3.412 |
| After 24 h CMJ height (cm) | 33.0 | 3.410 |
| Before 24 h CMJ height (cm) | 36.1 | 4.154 |
| After 48 h CMJ height (cm) | 34.6 | 3.856 |
| After 72 h CMJ height (cm) | 36.1 | 4.626 |
| After 96 h CMJ height (cm) | 36.3 | 3.935 |

Table 2. Post Hoc comparisons—CMJ maximum velocity (m/sn) and CMJ height (cm). ***p < 0.001, **p < 0.01.
Figure 2. CMJ maximum velocity (m/s) values of the players at different measurement times.

Figure 3. CMJ height (cm) values of the players at different measurement times.
strength development rates in different milliseconds and their relationships with maximum power, average power, and biochemical parameters, as well as the sensitivity of SSC in showing such neuromuscular fatigue. The jump heights obtained via the CMJ test are relatively precise and, thus, are given great importance in the literature. Researchers have also stated that these are valid and reliable tests to measure the fatigue associated with various activities, including common football activities, in which the function of the lower extremity is predominant.

In our study, it was found that the match triggered neuromuscular fatigue. This fatigue generally decreased 24 and 48 h after the match. The heights achieved in the CMJ test at the 24th and 48th hours after the match was significantly lower than the pre-match jump heights. A statistically significant difference was recorded between jump heights 24 h before the match and 24 h after the match (p > 0.001, Cohen’s d = 1.578). A statistically significant difference was also found in jump heights 24 h before the match as well as 48 h after (p > 0.01, Cohen’s d = 0.922). Previous studies support our findings—In these studies, CMJ heights decreased at the 24th and 48th hours after a match before increasing.

CMJ test performance might not be affected by the physiological neuromuscular fatigue that arises as a result of the affection of SSC by fatigue. The maximum velocity values examined in our study during CMJ might complicate the measurement of neuromuscular fatigue. Studies that have aimed to determine neuromuscular fatigue imposed on players after matches have considered the influence of maximum velocity during the CMJ
test, similar to our study. The maximum velocity parameter in the CMJ test is significantly different 24 h after a match compared to the pre-match level. There is also a statistically significant difference between the test 24 h before and 24 h after the match (p > 0.001, Cohen’s d = 1.210), researchers found that neuromuscular fatigue occurred after a match and decreased the maximum velocity attained during a CMJ test, which supports our results.

The values obtained from the tests we used to measure fatigue may be random. As a concrete example, the maximum velocity values in our CMJ test may have determined the fatigue in one measurement randomly while remaining undetected for the other measurement. Therefore, the reliability of the measured values must be determined in order to understand whether the measured values give random data. The reliability of both CMJ tests used in our study to measure fatigue was reported to be high in previous studies. The relationship between the internal and external game loads on the players during the game and the neuromuscular fatigue measurements seems statistically insignificant. In order to clarify this situation, it is thought that the relationship of more matches with neuromuscular fatigue measurements should be investigated in the future. Similar to our findings, some studies did not find a relationship between match internal and external loads and neuromuscular fatigue values.

There are some negative relations between internal and external loads and CMJ maximum velocity (m/s) values in the match, but these relations are statistically insignificant. Likewise, there are negative relations between internal and external loads and CMJ heights (cm) during the competition, but these relations are statistically insignificant. In general, as the activities performed during the match increase, the CMJ maximum velocity (m/s) and CMJ heights (cm) values decrease.

| Variable | TDC | 00–13.99 km/h | Y14–19.99 km/h | ≥ 20 km/h | ≥ 3 m/s #Acc (N) |
|----------|-----|---------------|---------------|-----------|-----------------|
| **Before 24 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.224 | -0.318 | 0.345 | -0.536 | -0.298 |
| p-value | 0.342 | 0.172 | 0.136 | 0.015 | 0.202 |
| Upper 95% CI | 0.243 | 0.145 | 0.683 | -0.122 | 0.166 |
| Lower 95% CI | -0.606 | -0.667 | -0.115 | -0.791 | -0.654 |
| **After 24 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.010 | -0.104 | 0.277 | -0.340 | -0.454 |
| p-value | 0.967 | 0.663 | 0.237 | 0.142 | 0.044 |
| Upper 95% CI | 0.435 | 0.355 | 0.641 | 0.121 | -0.014 |
| Lower 95% CI | -0.450 | -0.522 | -0.188 | -0.680 | -0.746 |
| **After 48 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.154 | -0.242 | 0.309 | -0.461 | -0.181 |
| p-value | 0.518 | 0.304 | 0.185 | 0.041 | 0.446 |
| Upper 95% CI | 0.310 | 0.225 | 0.661 | -0.023 | 0.285 |
| Lower 95% CI | -0.558 | -0.618 | -0.155 | -0.750 | -0.577 |
| **After 72 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.180 | -0.233 | 0.220 | -0.384 | -0.240 |
| p-value | 0.444 | 0.324 | 0.352 | 0.094 | 0.309 |
| Upper 95% CI | 0.285 | 0.234 | 0.604 | 0.070 | 0.227 |
| Lower 95% CI | -0.577 | -0.612 | -0.247 | -0.707 | -0.617 |
| **After 96 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.063 | -0.103 | 0.225 | -0.518 | -0.083 |
| p-value | 0.791 | 0.665 | 0.340 | 0.019 | 0.728 |
| Upper 95% CI | 0.390 | 0.356 | 0.607 | -0.098 | 0.373 |
| Lower 95% CI | -0.492 | -0.522 | -0.241 | -0.782 | -0.507 |
| **After 120 h CMJ height (cm)** | | | | | |
| Pearson’s r | -0.139 | -0.231 | 0.340 | -0.549 | -0.186 |
| p-value | 0.560 | 0.328 | 0.143 | 0.012 | 0.433 |
| Upper 95% CI | 0.324 | 0.236 | 0.680 | -0.141 | 0.280 |
| Lower 95% CI | -0.548 | -0.611 | -0.121 | -0.798 | -0.580 |

**Table 3.** Comparison of the match external loads and CMJ heights variables.
It is generally thought that fatigue affects the acceleration ability of the muscle during jumping, which, in turn, causes a decrease in velocity. The limitations of this study were that it examined fatigue changes over a one-week period and was conducted with a limited number of players. In future studies, it is recommended that more players are involved so that differences between playing positions can be examined alongside the effect of weekly match changes on fatigue during the following week and changes in different periods of the season.

### Conclusion

The neuromuscular fatigue imposed on football players after a match caused statistically significant differences in CMJ test performance before and after the match. Specifically, the jump heights obtained from the CMJ test before the match differed from the values recorded 24 and 48 h after the match. Likewise, it was found that the maximum velocity values in the CMJ test recorded 24 h after the match were different from the values recorded before the match, the neuromuscular fatigue values at the 24th hour after the match. Unlike with jump height, no significant difference was found between the pre-match values and the values recorded 48 h after the match. Meanwhile, no statistical correlation was found between the neuromuscular fatigue values of the players obtained at different time periods and the internal and external load values recorded during the match. It should be noted that fatigue continues until the after the match. Considering the effects of fatigue on players, complex situations such as adequate rest, nutrition, balanced training loads, effective training periodization, the appropriate selection of players to compete in the current week's match, and the determination of rest days during the week can create a road map for sports scientists, trainers, and strength conditioning coaches in light of the findings of this study.

| Variable | %HRmax 50–59 | %HRmax 60–69 | %HRmax 70–79 | %HRmax 80–89 | %HRmax 90–100 |
|----------|--------------|--------------|--------------|--------------|--------------|
| Before 24 h CMJ height (cm) | | | | | |
| Pearson's r | 0.176 | 0.191 | −0.071 | −0.151 | −0.180 |
| p-value | 0.457 | 0.421 | 0.766 | 0.526 | 0.448 |
| Upper 95% CI | 0.574 | 0.584 | 0.384 | 0.313 | 0.285 |
| Lower 95% CI | −0.289 | −0.275 | −0.498 | −0.556 | −0.577 |
| After 24 h CMJ height (cm) | | | | | |
| Pearson's r | 0.301 | 0.169 | −0.033 | −0.202 | −0.284 |
| p-value | 0.196 | 0.475 | 0.890 | 0.393 | 0.225 |
| Upper 95% CI | 0.656 | 0.569 | 0.416 | 0.264 | 0.181 |
| Lower 95% CI | −0.163 | −0.295 | −0.469 | −0.592 | −0.645 |
| After 48 h CMJ height (cm) | | | | | |
| Pearson's r | 0.078 | 0.004 | −0.013 | 0.030 | −0.134 |
| p-value | 0.745 | 0.986 | 0.957 | 0.901 | 0.572 |
| Upper 95% CI | 0.503 | 0.446 | 0.432 | 0.466 | 0.328 |
| Lower 95% CI | −0.378 | −0.439 | −0.453 | −0.418 | −0.544 |
| After 72 h CMJ height (cm) | | | | | |
| Pearson's r | 0.061 | 0.236 | −0.044 | −0.163 | −0.090 |
| p-value | 0.797 | 0.316 | 0.854 | 0.492 | 0.705 |
| Upper 95% CI | 0.491 | 0.615 | 0.406 | 0.301 | 0.367 |
| Lower 95% CI | −0.392 | −0.230 | −0.477 | −0.565 | −0.512 |
| After 96 h CMJ height (cm) | | | | | |
| Pearson's r | 0.049 | 0.019 | −0.035 | −0.002 | −0.050 |
| p-value | 0.837 | 0.936 | 0.883 | 0.992 | 0.833 |
| Upper 95% CI | 0.481 | 0.458 | 0.414 | 0.441 | 0.401 |
| Lower 95% CI | −0.402 | −0.427 | −0.470 | −0.444 | −0.482 |
| After 120 h CMJ height (cm) | | | | | |
| Pearson's r | 0.349 | −0.025 | 0.062 | −0.228 | −0.175 |
| p-value | 0.131 | 0.917 | 0.795 | 0.333 | 0.461 |
| Upper 95% CI | 0.686 | 0.422 | 0.491 | 0.238 | 0.290 |
| Lower 95% CI | −0.111 | −0.462 | −0.391 | −0.609 | −0.573 |

Table 4. Comparison of the match internal loads and CMJ heights variables.
| Variable | TDC | 00–13.99 km/h | Y14–19.99 km/h | ≥ 20 km/h | ≥ 3 m/s #Acc (N) |
|----------|-----|--------------|----------------|-----------|-----------------|
| Before 24 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.216 | 0.199 | 0.035 | −0.054 | 0.314 |
| p-value | 0.360 | 0.401 | 0.883 | 0.820 | 0.178 |
| Upper 95% CI | 0.601 | 0.589 | 0.470 | 0.398 | 0.664 |
| Lower 95% CI | −0.250 | −0.267 | −0.414 | −0.485 | −0.149 |
| After 24 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.240 | 0.182 | 0.085 | 0.046 | 0.367 |
| p-value | 0.308 | 0.443 | 0.722 | 0.849 | 0.112 |
| Upper 95% CI | 0.617 | 0.578 | 0.508 | 0.478 | 0.696 |
| Lower 95% CI | −0.227 | −0.283 | −0.372 | −0.405 | −0.091 |
| After 48 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.121 | −0.052 | 0.279 | 0.177 | −0.012 |
| p-value | 0.611 | 0.829 | 0.234 | 0.456 | 0.959 |
| Upper 95% CI | 0.535 | 0.400 | 0.642 | 0.574 | 0.432 |
| Lower 95% CI | −0.340 | −0.483 | −0.187 | −0.288 | −0.452 |
| After 72 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.329 | 0.314 | 0.014 | −0.022 | 0.353 |
| p-value | 0.156 | 0.177 | 0.953 | 0.925 | 0.127 |
| Upper 95% CI | 0.674 | 0.665 | 0.454 | 0.424 | 0.688 |
| Lower 95% CI | −0.133 | −0.149 | −0.431 | −0.460 | −0.106 |
| After 96 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.301 | 0.251 | 0.063 | 0.052 | 0.203 |
| p-value | 0.197 | 0.285 | 0.791 | 0.829 | 0.391 |
| Upper 95% CI | 0.656 | 0.624 | 0.492 | 0.483 | 0.592 |
| Lower 95% CI | −0.163 | −0.215 | −0.390 | −0.400 | −0.263 |
| After 120 h CMJ maximum velocity (m/sn) | | | | | |
| Pearson's r | 0.219 | 0.135 | 0.084 | 0.232 | 0.230 |
| p-value | 0.354 | 0.570 | 0.724 | 0.325 | 0.328 |
| Upper 95% CI | 0.603 | 0.545 | 0.508 | 0.612 | 0.611 |
| Lower 95% CI | −0.248 | −0.327 | −0.372 | −0.235 | −0.236 |

Table 5. Comparison of the match external loads and CMJ maximum velocity variables.
Data availability
The datasets generated during and analyzed during the current study are available from Z.A on reasonable request.

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| Variable | %HRmax 50–59 | %HRmax 60–69 | %HRmax 70–79 | %HRmax 80–89 | %HRmax 90–100 |
|----------|--------------|--------------|--------------|--------------|--------------|
|          |              |              |              |              |              |
| Before 24 h maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | − 0.009      | − 0.201      | 0.111        | 0.168        | − 0.085      |
| p-value | 0.968 | 0.395 | 0.642 | 0.480 | 0.723 |
| Upper 95% CI | 0.435 | 0.265 | 0.527 | 0.568 | 0.372 |
| Lower 95% CI | − 0.450 | − 0.591 | − 0.349 | − 0.297 | − 0.508 |
| After 24 h CMJ maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | 0.115 | − 0.267 | − 0.114 | 0.232 | − 0.052 |
| p-value | 0.630 | 0.254 | 0.633 | 0.325 | 0.829 |
| Upper 95% CI | 0.530 | 0.199 | 0.346 | 0.612 | 0.400 |
| Lower 95% CI | − 0.345 | − 0.635 | − 0.530 | − 0.235 | − 0.483 |
| After 48 h CMJ maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | 0.203 | − 0.051 | 0.027 | 0.039 | − 0.284 |
| p-value | 0.390 | 0.832 | 0.909 | 0.871 | 0.224 |
| Upper 95% CI | 0.593 | 0.401 | 0.464 | 0.473 | 0.181 |
| Lower 95% CI | − 0.263 | − 0.482 | − 0.420 | − 0.411 | − 0.646 |
| After 72 h CMJ maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | − 0.046 | − 0.375 | 0.069 | 0.304 | 0.017 |
| p-value | 0.847 | 0.103 | 0.773 | 0.192 | 0.944 |
| Upper 95% CI | 0.405 | 0.081 | 0.496 | 0.658 | 0.456 |
| Lower 95% CI | − 0.479 | − 0.701 | − 0.385 | − 0.160 | − 0.429 |
| After 96 h CMJ maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | 0.126 | − 0.242 | 0.225 | 0.121 | − 0.256 |
| p-value | 0.595 | 0.303 | 0.340 | 0.612 | 0.277 |
| Upper 95% CI | 0.539 | 0.224 | 0.607 | 0.535 | 0.211 |
| Lower 95% CI | − 0.335 | − 0.619 | − 0.241 | − 0.340 | − 0.627 |
| After 120 h CMJ maximum velocity (m/sn) |              |              |              |              |              |
| Pearson's r | − 0.082 | − 0.263 | 0.132 | 0.362 | − 0.201 |
| p-value | 0.732 | 0.263 | 0.580 | 0.117 | 0.395 |
| Upper 95% CI | 0.374 | 0.203 | 0.543 | 0.693 | 0.265 |
| Lower 95% CI | − 0.506 | − 0.632 | − 0.330 | − 0.096 | − 0.591 |

Table 6. Comparison of the match internal loads and CMJ maximum velocity variables.
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Author contributions
Z.A., Y.O, F.M.C., H.N., Y.B and M.G., had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. The authors contributed to this work as follows. Study concept and design: Z.A., Y.O, F.M.C., H.N., Y.B and M.G., Acquisition of data: Z.A., Y.O, F.M.C., H.N., Y.B and M.G. Analysis and interpretation of data: Z.A., Y.O, F.M.C., H.N., Y.B and M.G. Drafting of the manuscript Z.A., Y.O, F.M.C., H.N., Y.B and M.G. Critical revision of the manuscript for intellectual content: Z.A., Y.O, F.M.C., H.N., Y.B and M.G.

Competing interests
The authors declare no competing interests.

Additional information
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