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The Effect of a Repeated Sprint Training Session on Neuromuscular Acute Fatigue

O efeito de uma sessão de treinamento de sprints repetidos sobre a fadiga aguda neuromuscular

El efecto de una sesión de entrenamiento de sprint repetidos sobre la fatiga neuromuscular aguda

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Abstract

The performance in countermovement jump (CMJ) may represent a practical and noninvasive way to control the effects imposed by loads of a training session on fatigue. The present study aimed to investigate the acute influence of repeated sprint training (RST) protocol on neuromuscular performance, measured with countermovement jump (CMJ) and a 40m sprint test, at different moments - during and post training; and to check if the sprint decrement obtained throughout the RST protocol would be related to the acute decrement in CMJ. The sample was composed of 11 male university-level team-sport athletes (22.66±1.97 years, 75.68±7.84 kg, 1.78±2.06 m). After the familiarization process, the volunteers participated in the CMJ baseline test, RST training session, CMJ test during the RST training, CMJ test after RST training (2h, 24h and 48h). The minimal individual difference (MID) was used to identify actual individual changes in CMJ and sprint performance. Pearson's correlation coefficient, with 95% percentile bootstrap confidence intervals, was used to identify the relationship between CMJ and sprint performance. The RST training protocol was able to induce real CMJ and sprint performance changes. The CMJ performance returned to initial values 24 and 48 hours after RST training. The sprint performance remained altered during the RST, which was expected. However, performance remained below MID at 2h, 24h and 48h after the training protocol. The performance at CMJ and sprint showed a positive and significant correlation. A multi-parameter approach should be adopted to monitor the status of neuromuscular fatigue.

Keywords: Fatigue. Training control. Countermovement jump. Running.

Resumo

O desempenho no salto contra movimento (SCM) pode representar uma forma prática e não invasiva de monitoramento e controle do treinamento. O presente estudo objetivou investigar a influência aguda de um protocolo de treinamento de sprints (RST) repetidos no desempenho neuromuscular, avaliado através do SCM e de um teste de velocidade (40 metros), em diferentes períodos; e verificar se o decréscimo de sprint obtido ao longo do protocolo RST estaria relacionado ao decréscimo agudo no SCM. Participaram 11 atletas (22,66±1,97 anos, 75,68±7,84 kg, 1,78±2,06 metros) masculinos de equipes esportivas universitários. Os voluntários foram submetidos à avaliação de SCM. A sessão de treinamento (RST) aconteceu 48 horas após o protocolo de avaliação basal. Os testes de monitoramento de SCM aconteceram durante e após a sessão de treinamento (2, 24 e 48 horas). A diferença individual mínima (DIM) foi usada para identificar mudanças individuais reais no SCM e no desempenho do sprint. O coeficiente de correlação de Pearson, com intervalos de confiança de 95%, foi utilizado para identificar a relação entre o desempenho no SCM e no sprint. Resultados indicam que protocolo de treinamento RST foi capaz de induzir alterações no SCM e no sprint. O desempenho do SCM retornou aos valores basais 24 e 48 horas após o treinamento do RST. O desempenho do sprint permaneceu alterado durante o RST. Entretanto, o desempenho permaneceu abaixo da DIM às 2, 24 e 48 horas após o protocolo de treinamento. O desempenho entre SCM e sprint apresentou uma correlação positiva e significativa.

Unitermos: Fadiga. Controle de treinamento. Salto contra movimento. Corrida.

Resumen

El rendimiento de salto contra movimiento (SCM) puede representar una forma práctica y no invasiva de monitorear y controlar el entrenamiento. Este estudio tuvo como objetivo investigar la influencia aguda de un protocolo de entrenamiento de sprints repetidos (ESR) sobre el rendimiento neuromuscular, evaluado a través del SCM y un test de velocidad (40m), en diferentes períodos; y verificar si la disminución del sprint obtenida a lo largo del protocolo de ESR estaría relacionada con la disminución aguda del SCM. Participaron once atletas masculinos (22,66±1,97 años, 75,68±7,84 kg, 1,78±2,06m) de equipos deportivos universitarios. Los voluntarios se sometieron a una evaluación de SCM. La sesión de entrenamiento (ESR) tuvo lugar 48 horas después del protocolo de evaluación inicial. Las pruebas de seguimiento del SCM se realizaron durante y después de la sesión de entrenamiento (2, 24 y 48hs). La diferencia individual mínima (DIM) se utilizó para identificar cambios individuales reales en SCM y rendimiento del sprint. Se utilizó el coeficiente de correlación de Pearson, con intervalos de confianza del 95%, para identificar la relación entre SCM y rendimiento de sprint. Los resultados indican que el protocolo de ESR induce cambios en SCM y sprint. El rendimiento de SCM volvió a valores de referencia 24 y 48hs después del ESR. El rendimiento del sprint se mantuvo alterado durante el ESR. Sin embargo, el rendimiento se mantuvo debajo de la DIM a las 2, 24 y 48hs después del protocolo de entrenamiento. El rendimiento entre SCM y sprint mostró correlación positiva y significativa.

Palabras clave: Fatiga. Control de entrenamiento. Salto contra movimiento. Carrera.

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Introduction

Repeated-sprint training (RST) is considered a critical training method in team sports. It is well known that RST effects may depend on several variables such as the duration of the protocol and repeated-sprint methodology (Beato et al., 2019). Analyzing training loads is a fundamental task in sports science (Pinheiro et al., 2022) Vertical jump (VJ) is a common task in sports performance, and it is one of the critical parameters in monitoring training adaptations (Pagaduan et al., 2019). The countermovement jump (CMJ) has been used in high-performance sport to monitor changes in neuromuscular readiness, fatigue, and subsequent recovery in response to training loads, as well as to quantify adaptations to training programs. (Claudino et al., 2017; Gathercole et al., 2015a; Heishman et al., 2018; Heishman et al., 2020; Rey et al., 2020)

Neuromuscular fatigue can be present for up to 48 hours post training (Wu et al., 2019). Common signs of fatigue include decreased velocity of muscle shortening, post contraction relaxation, loss of height in vertical jumps, and modification of various biochemical markers (Brasch et al., 2019; Claudino et al., 2017; Oliver et al., 2015). Previous research has used CMJ to monitor changes in physical performance after running tasks. Previous research assessed whether CMJ performance could predict running performance (Markström, & Olsson, 2013). The peak force relative to body mass and the height achieved in the CMJ were able to predict the maximum running velocity performance in 10 meters and 60 meters tasks. When the CMJ showed higher values of peak force and height, improvements in running performance were also observed. This significant correlation seems to be explained by the presence of physio mechanical characteristics in common between the CMJ and the running (Markström, & Olsson, 2013; Kale et al., 2009). Research indicates that the fatigue process generates biomechanical changes of movement in the lower limbs, both in running and jumping tasks (Yu et al., 2020). Thus, it is expected that CMJ decrement could be related to sprint performance decrement (i.e., running fatigue).

Training load monitoring may ensure that the subject achieve an adequate training stimulus, minimize the negative consequences of training, and enhance readiness (Gabbett, 2016; Hamlin et al., 2019; McGuigan et al., 2020; Ryan et al., 2020). Due to its robust nature in both reliability and validity, the CMJ test has become accepted as the reference standard test for monitoring neuromuscular fatigue status within sport environments (Garrett et al., 2019; Gathercole et al., 2015b), and is generally performed using a digital optical encoder, force plate or contact mat (Garrett et al., 2020). Claudino et al. (2017) conducted a meta-analysis on the use of counter movement jump as a neuromuscular status monitor. Based on the meta-analysis, average CMJ height was more sensitive in detecting CMJ fatigue and super compensation. For other testing (e.g., sprint testing) it is recommended that average values be used to monitor training effects.

To the best of our knowledge, no research was found to identify the relationship of CMJ and sprint performance at different moments after a RST protocol, using the analysis of the minimum individual difference over different moments. Evidence shows that the magnitude of change in neuromuscular fatigue begins within the first 24 hours, with values peaking between 24 and 48 hours (Ispirlidis et al., 2008). It is necessary to understand the behavior of neuromuscular fatigue throughout the days using different parameters. Thus, this study aimed to investigate the acute influence of repeated sprint training (RST) protocol on neuromuscular performance, measured with countermovement jump (CMJ) and a 40 meters sprint test, at different moments - during and post training; and to check if the sprint decrement obtained throughout the RST protocol would be related to the acute decrement in CMJ.

Methods

Sample

Participated in the study 11 male university-level team-sport athletes (22.66 ± 1.97 years, 75.68 ± 7.84 kg, 1.78 ± 2.06 meters), with no history of lower limb injury (previous 6 months before the study) and who were not involved in any running, jumping or strength training program during the study period. To identify pre-training status, all participants answered the Physical Activity Readiness Questionnaire (PAR-Q).

Ethical standards

This study was approved by the ethics and research committee at the Federal University (CAAE: 11751513.7.0000.5149). Volunteers were previously informed about all methodological procedures of the research and signed the informed consent form agreeing to participate voluntarily in the study. All participants signed the Term of Free and Informed Consent. The procedures performed in the study were in strict accordance with the Declaration of Helsinki.

Procedures

This is a cross-sectional study, where the acute effect of fatigue generated by a repeated sprint running training session on CMJ and sprint performance was analyzed. After the familiarization process, the volunteers participated in the CMJ baseline test, RST training session, CMJ test during the RST training, CMJ test after RST training (2, 24 and 48 hours). All the procedures are list in the Table 1.

Table 1. *Time-lime of the procedures*

Phase	Procedures	Time line
CMJ Familarization	Familiarization Protocol	Meeting 1
CMJ Familarization	Familiarization Protocol	Meeting 2 (48 hours interval)
CMJ and Sprint Baseline Test	Baseline test	Pre RST Training test (48 hours interval)
Repetead Sprint training protocol	Training session	RST Training
CMJ Test - between sets	Monitoring	During the RST training
CMJ Test - 2 hours	Monitoring	2 hours post training
CMJ Test - 24 hours	Monitoring	24 hours post training
CMJ Test - 48 hours	Monitoring	48 hours post training

Source: Authors

CMJ Familiarization

At the beginning of the study, the volunteers participated in the familiarization process with countermovement jump. The initial procedure was performed on the Jump test vertical jump mat (*Hidrofit Ltda; Belo Horizonte, Brazil, precision of 0.1 cm*), connected to Multisprint software (*Hidrofit Ltda; Belo Horizonte, Brazil*). A CMJ series was performed, with 1-min breaks between the attempts, until the performance stabilized. The performance was considered stabilized when a sequence of 8 jumps was similar to the performance achieved previously with a sequence of 8 jumps. This familiarization session was repeated in 48 hours, and the individual was considered familiarized when the performance remained stabilized between 2 consecutive sessions. (Claudino et al., 2012; Claudino et al., 2017)

CMJ and Sprint Test - Baseline

The baseline CMJ test was composed of 4 jumps, with an interval of 1 minute. The CMJ test was performed on a bipedal force platform PLA3-1D-7KN/JBA Zb (*Staniak; Warsaw, Poland, precision of 1 N*). The data were extracted using Matlab software version 9.7.0 (*MathWorks; Natick, EUA*), with a low-pass filter, a 4 a Butterworth filter and an ordinance with a cut-off frequency of 90 Hz. The sprint test was composed of 3 maximum running repetitions (distance of 40 meters), separated by 1 minute interval. The running velocity was recorded through a system of photocells, positioned at 0, 10 and 40 meters, connected to a computer by the software Mutlisprint Full (*version 3.5.7, Hidrofit LTDA, Brazil*). The CMJ and sprint test were performed 48 hours after the familiarization protocol, with a 20-minute interval between each test.

Repeated sprint training (RST) protocol

The running training session was adapted from Bishop et al. (2019) and was composed of 4 blocks of 6x40 meters running series. Between each sprint series a 30 second interval was provided, and between each block the interval was 2 minutes. The individuals were instructed to run at the maximum possible velocity. The running velocity was recorded through a system of photocells, positioned at 0, 10 and 40 meters, connected to a computer by the software Mutlisprint Full (*version 3.5.7, Hidrofit LTDA, Brazil*). To determine the fatigue rate in the training session, the percentage difference between the average velocity of the first and last running blocks was determined.

Monitoring Tests - between sets of RST protocol and post training

Between the running series of the RST training protocol the individuals performed 4 CMJ, separated by 60-second interval (Szmuchrowski et al., 2012). The force platform (*PLA3-1D-7KN/JBA Zb, Staniak, Warsay, Poland, accuracy 1N*) was used. After two hours another monitoring test was carried, also including a sprint test. The sprint test consisted of 3 sprints, with a distance of 40 meters and 1 minute interval. The same evaluation protocols for CMJ and sprint were performed 24 and 48 hours after the training.

Individual minimum difference

The minimal individual difference (MID) was used to identify actual individual changes in CMJ and sprint performance. The MID represents the maximal variation of random error. A real alteration of performance was considered when a modular difference between 2 measures was observed to be superior to the MID value (Eq. 1). The MID was determined from CMJ values obtained during the familiarization and baseline tests. (Claudino et al., 2012)

$$MID = SEM \times 2.145 \times \sqrt{2} \qquad (1)$$

$\text{SEM} = \sqrt{\text{mean square of error}}\ (\text{MS}_{\text{error}})$

$2.145 = t(14)$ as $p < 0.05$ (Confidence Interval of 95 %)

Statistical analysis

The descriptive analysis of the data was performed, and the results are presented on mean and standard deviation. The Shapiro-Wilk Test was used to check the normality of the data. As the data showed normal distribution, parametric tests were used. To verify the familiarity of the individuals with the CMJ, paired t-tests were performed. The individuals were considered familiar when the values found did not present significant differences (Claudino et al., 2012). The effect size (ES) statistic was calculated to determine the magnitude of the effects generated by RST training on CMJ performance and was assessed using the following criteria: 0.2 = trivial, 0.2-0.6 = small effect, 0.6-1.2 = moderate effect, 1.2-2.0 = large effect and .2.0 = very large. (Cohen, 1988)

Pearson's correlation coefficient, with 95% percentile bootstrap confidence intervals, was used to identify the relationship between CMJ performance at different moments (baseline; during RST training; 2, 24 and 48 hours after RST training) and sprint performance on the RST training. The magnitude of correlation coefficients was considered trivial (r<.1), small (.1<r<.3), moderate (.3<r<.5), large (.5<r<.7), very large (.7<r<.9), almost perfect (r>.9) or perfect (r=1) (Hopkins, 2002). The significance level adopted for all tests was set p<0.05. All data were analyzed using the Statistical Package for the Social Sciences (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) software.

Results

The Table 2 presents the descriptive data in relation to the CMJ and sprint performance.

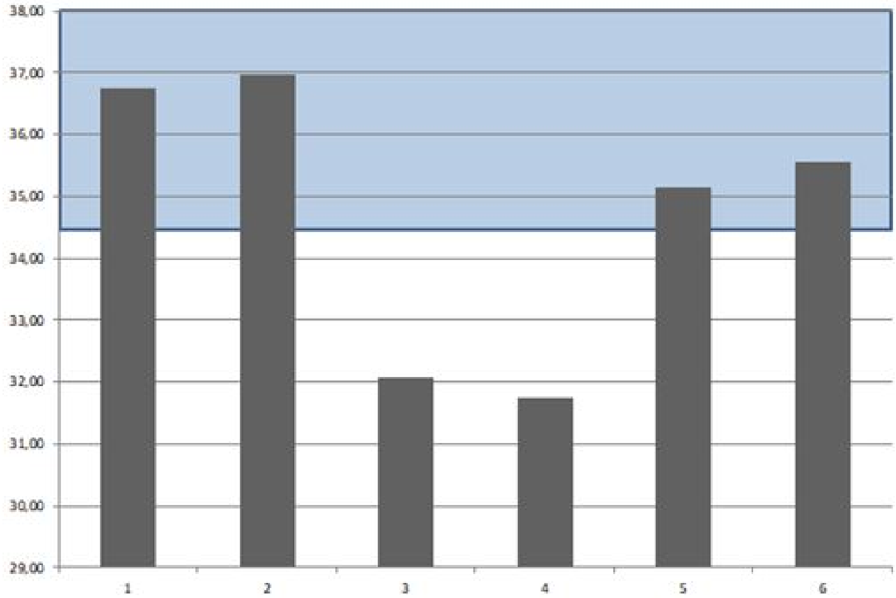
Table 2. *CMJ and Sprint Performance*

	Performance
CMJ baseline	36.98 ± 5.89 (cm)
CMJ during RST training	32.07 ± 5.51 (cm)
CMJ 2 hours post training	31.75 ± 5.40 (cm)
CMJ 24 hours post training	35.13 ± 5.60 (cm)
CMJ 48 hours post training	35.56 ± 5.39 (cm)
Sprint Baseline	6.77 ± .51 (m/s)
RST Training	5.91 ± .33 (m/s)
Sprint Test 2 hours post training	5.97 ± .51 (m/s)
Sprint Test 24 hours post training	6.42 ± .48 (m/s)
Sprint Test 48 hours post training	6.40 ± .59 (m/s)

Source: Authors

The Graph 1 presents the CMJ performance at different times and indicates the MID. It was observed that CMJ performance was only outside the MID during the training and 2 hours after the training.

Graph 1. *CMJ performance at different moments*

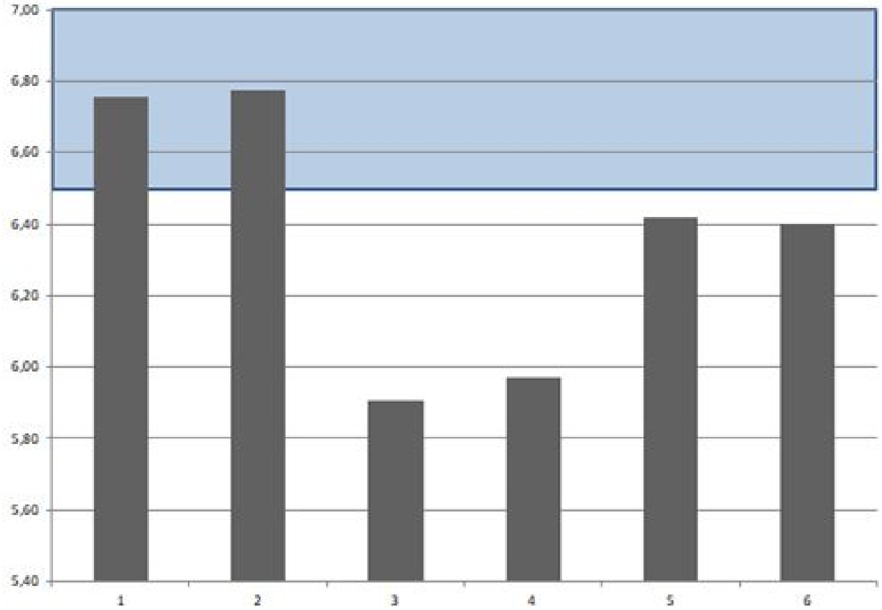


1 = average performance (in cm) in the familiarization phase; 2= average performance (in cm) in the baseline test; 3 = average performance (in cm) during the RST training; 4 = average performance (in cm) 2 hours after the RST training; 5 = average performance (in cm) 24 hours after the RST training; 6 = average performance (in cm) 48 hours after the RST training. Blue area represents the MID. Source: Authors

The magnitude of the effects generated by RST training on CMJ performance were 0.92 at 2 hours after the RST protocol, 0.32 at 24 hours after the RST protocol and 0.27 at 48 hours after the RST protocol ($p<0.05$).

The Graph 2 presents the sprint performance at different times and indicates the MID. It was observed that sprint performance was outside the MID during the training; 2, 24 and 48 hours after the training.

Graph 2. *Sprint performance at different moments*



1 = average sprint performance (in m/s) in the familiarization phase; 2= average sprint performance (in m/s) in the baseline test; 3 = average sprint performance (in m/s) during the RST training; 4 = average sprint performance (in m/s) 2 hours after the RST training; 5 = average sprint performance (in m/s) 24 hours after the RST training; 6 = average sprint performance (in m/s) 48 hours after the RST training. Blue area represents the MID. Source: Authors

The magnitude of the effects generated by RST training on sprint performance were 1.57 at 2 hours after the RST protocol, 0.71at 24 hours after the RST protocol and 0.67 at 48 hours after the RST protocol ($p<0.05$).

Descriptive statistics

The average performance in the CMJ after the sprint running training session showed a significant reduce compared to the means obtained before the session ($p = 0.001$), being -1.66 the effect size. The same was observed for the mean running velocities obtained at the beginning and end of the training session ($p = 0.0001$), with an effect size of -1.88. The Table 3 shows the correlations between CMJ and sprint performance.

Table 3. *Correlation between CMJ and sprint performance at different times evaluated*

	Sprint Baseline	**RST Training**	**Sprint Test 2 hours post training**	**Sprint Test 24 hours post training**	**Sprint Test 48 hours post training**
CMJ baseline	0.857*	0.626*	0.022	0.709*	0.649*
CMJ during RST training	0.677*	0.617*	0.199	0.504	0.485
CMJ 2h post training	0.346	0.519	0.631*	0.157	0.172

CMJ 24h post training	0.727*	0.526	0.042	0.740*	0.745*
CMJ 48h post training	0.773*	0.501	0.151	0.780*	0.763*

* correlation is significant at the level 0.05. Source: Authors

Discussion

The primary research question in this study was to investigate the acute influence of repeated sprint training (RST) protocol on neuromuscular performance, measured with the CMJ and a 40 meters sprint test, at different moments (during and post training) thought the MID analysis. Additionally, it was intended to check if the sprint decrement obtained throughout the RST protocol would be related to the acute decrement in CMJ. The present findings indicated the RST training protocol was able to induce real CMJ performance changes (i.e., changes greater than the MID) during the RST training and 2 hours after the RST training. The CMJ performance returned to initial values 24 and 48 hours after RST training. The sprint performance remained altered during the RST, which was expected. However, performance remained below MID at 2, 24 and 48 hours after the training protocol.

Neuromuscular fatigue analysis, as measured by the change in performance outside the MID, indicated that subjects may be recovered to the vertical jump task from 24 hours after the stimulus, but still underperformed in the running task. These data indicate the importance of multi-parameter monitoring over time. In research with football players, Pinheiro et al. (2018) suggested that an integrated list of load monitoring tools should be adopted, as the ability to effectively monitor fatigue is highly important for coaches and sport scientists. (Hughes et al., 2019)

The CMJ performance has been used to monitor the effects of strength, plyometric, and endurance training (Claudino et al., 2017). Previous studies point to the existence of a significant correlation between CMJ performance and sprint running in high performance sport levels (Claudino et al., 2017; Garrett et al., 2019; Thorpe et al., 2017; Zabaloy et al., 2020). Jiménez-Reyes (2019) suggested that CMJ height might be used as a simple method for determining fatigue during sprint training, and to individualize load prescriptions in male high-level sprinters. In the present study it was observed that the acute reduction in sprint running performance was accompanied by a reduction in performance at the CMJ. The gradual decrease in running velocity and vertical jump height that occurred during the repeated sprint training protocol can be interpreted as evidence of impaired neuromuscular function. (Jiménez-Reyes et al., 2016; Jiménez-Reyes et al., 2019)

The present study evaluated the correlation between performance drop in CMJ and in the running velocity. The baseline performance at CMJ correlated with the baseline sprint performance (0.857), with the running performance during the RST protocol (0.626), and with the sprint performance 24 hours (0.709) and 48 hours (0.649) after RST. Despite the higher inflammatory disorders tend to peak between 48 hours and 72 hours after the training stimulus (Ispirlidis, 2008), in this study there was a higher correlation between CMJ and sprint 24 hours after the training protocol. The CMJ during RST training has shown a correlation with sprint performance during RST training (0.617), thus indicating that CMJ test can be a tool for acute control of training load in repeated sprint tasks.

The performance at CMJ 2 hours after the RST training only showed correlation with the sprint performance in the same condition (0.631). The CMJ 24 hours post training correlated with sprint performance in baseline assessment (0.727), 24 (0.740) and 48 hours after RST training (0.745). And the CMJ 48 hours post training correlated with sprint performance in baseline assessment (0.773), 24 (0.780) and 48 hours after RST training (0.763). These findings corroborate findings from previous research (Markström, & Olsson, 2013), and reinforce the correlation of performance at CMJ with the sprint even in different RST protocols. The limitation of the study is the cross-sectional approach. However, the results of this study may contribute to establish the use of the CMJ as a parameter to monitor response to repeated sprint training.

Conclusion

The acute influence of an RST training protocol on CMJ and sprint performance was analyzed. Through the analysis of the minimum individual difference, it was observed that the performance in the vertical jump task returned to the basal values 24 hours after the training, while the performance in the sprint did not return to the basal values after the training. The performance at CMJ and sprint showed a positive and significant correlation. It is concluded that neuromuscular fatigue must be monitored in a multi-parameter way. Future research should investigate the influence of different STR protocols on neuromuscular fatigue.

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