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Short-term effects of rolling massage on energy cost of running and power of the lower limbs

Original Investigation

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Running head: Self-massage effects on running and jumping

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Abstract

Purpose: Self-myofascial release (SMFR) is a type of self-massage that is becoming popular among athletes. However, SMFR effects on running performance have not been investigated yet. The aim of the present study was to evaluate the effects of SMFR on cost of running (Cr). In addition, we evaluated the effects of SMFR on lower limbs muscle power. **Methods:** The measurement of Cr and lower limb muscle power during squat jump (SJ) and counter movement jump (CMJ) were performed before (PRE), immediately after (POST) and 3hours after (POST 3h) a SMFR protocol (experimental condition). In the "control condition" testing session, the same measurements were performed without undergoing the SMFR protocol. Experimental and control conditions were tested in a randomized order. **Results:** Cr at POST trended to increase as compared to PRE (+6.2±8.3%, p=0.052), while at POST 3h Cr was restored to PRE values (+0.28±9.5%, p=0.950). In the experimental condition, no significant "Time" effect was observed for maximal power exerted during SJ. On the other hand, maximal power exerted during CMJ at POST and POST 3h was significantly higher than that observed at PRE (+7.9±6.3%, p=0.002; and +10.0±8.7%, p=0.004, respectively). The rate of force development measured during CMJ also increased after SMFR, reaching statistical significance at 200 ms from force onset at POST 3h (+38.9%, p=0.024). **Conclusions:** an acute use of foam roller for SMFR performed immediately prior to running may negatively affect the endurance running performance, while its use should be added before explosive motor performances that include stretch-shortening cycles.

Keywords: mechanics; energetics; stiffness; jump; foam roller; self-myofascial release

Introduction

Many athletes commonly use different strategies (i.e. dynamic or static stretching, massages, self-myofascial release) before and/or after competitions or training sessions in order to improve flexibility, accelerating recovery time and decreasing injury risk.[1] However, in the literature there are conflicting results about the effects of these strategies on performance.[1] Indeed, static stretching, which is one of the most common used, improves flexibility but it can negatively affects the leg press one repetition maximum, muscle strength endurance, 20-m sprint performance and vertical jump height.[2-5] Also, static stretching does not seem effective for promoting shorter recovery time.[6] However, the negative effects of static stretching on neuromuscular performance may be minimized if static stretching is followed by a dynamic activity.[7] On the other hand, dynamic stretching improves flexibility along with increasing torque during an isokinetic exercise and it seems to be more suitable for improving performance.[2]

Self-myofascial release (SMFR) is a type of self-massage that can be performed by the subject himself rather than by a clinician.[8] The most common devices used for SMFR are foam roller and roller massager. SMFR can promote short-term flexibility improvement, and it does not seem to have negative effects on performance.[2,3,9-11] In fact, no differences in maximal force and power were detected after a SMFR protocol.[2,12] Moreover, SMFR has been shown effective for reducing delay onset muscle soreness (DOMS), accelerating the recovery after intense and eccentric training sessions.[9] However, Casanova et al.[13] showed that rolling massage treatment does not limit the negative effects of exercise-induced muscle damage caused by five sets of twenty unilateral calf rises. SMFR application time seems important for its effect on muscle function. Short application time (<30 s) seems to have no significant effects on performance.[12] Thus, for SMFR longer applications are suggested, particularly for wide muscles.[14] The mechanisms underlying SMFR-induced adaptations on muscle function are not completely understood; however, they conceivably include biomechanical, physiological, neurological and psychological components.[8] In particular, SMFR may influence the connective fascia characteristics, and specifically its water content and stiffness.[15] In fact, the traction and compression of the fascia leads to a loss of water, which is followed by re-hydration that reaches its peak about 3-4 hours after the mechanical stress application.[15] This "sponge-effect" was reported while examining an *in vitro* model; thus, the effects of traction and compression might be different compared to those obtained *in vivo*. Also, another study suggested that heavy rolling massage and manual massage over tender points can increase the pain threshold by acting both at peripheral level and at central level.[16]

In spite of the increasing number of studies that have examined the influence of SMFR on sport performance,[8] to the best of our knowledge the effects of SMFR on running performance have not been investigated yet. Energy cost of running (Cr) plays a relevant role in determining the performance among middle and long distance runners along with the maximal oxygen uptake and the fraction of its maintained during the effort.[17] In turn, our research group has also observed that Cr is affected by muscle power of lower limb extensors.[17] Hence, the primary objective of the present study was to evaluate the effects of SMFR treatment on Cr. In addition, we evaluated the effects of SMFR on lower limbs muscle power. Our hypothesis is that Cr and lower limb muscle power would be impaired immediately after SMFR, possibly because of the muscle stiffness alteration caused by the loss of water content in the fascia. On the other hand, Cr and lower limb muscle power may be improved 3 hours after SMFR treatment, possibly because fascia water content and consequently muscle stiffness might be higher than before treatment.[15]

Methods

Subjects

Thirteen active sport students (mean age: 26.3±5.3 years) were enrolled in the study (Table 1). Participants reported to practice different sports (i.e. soccer, track and field, mountain running, parkour) for 9.9±3.5 hours·week^{-1} on average. They were informed about the study protocol, read and signed an informed consent before starting the measurements. The study was approved by the local Institutional Review Board.

Experimental Design

In this randomized crossover design study, participants visited the laboratory three times. During the first day, we collected informed consent, stature, body mass and body composition. Then, the subjects familiarized with all the testing procedures (treadmill running, squat jump (SJ), counter movement jump (CMJ) and SMFR treatment). During the "experimental condition" testing session, subjects ran ten minutes on a treadmill at self-selected speed and Cr was calculated for the last two minutes of the trial. Immediately after the treadmill run, participants performed three SJ and three CMJ on an Explosive Ergometer (EXER). The rest period between each jump was 3 minutes. The trial with the highest peak power exerted during SJ and CMJ was considered for further analysis. After the lower limb muscle power assessment, subjects underwent a sixteen-minute SMFR treatment with the assistance of a therapist. Immediately after the SMFR treatment and 3 hours after the treatment, participants repeated the running assessment at the same speed that was self-selected during the first trial, SJ and CMJ. During the "control condition" testing session, subjects performed the same procedures except for the SMFR treatment (Figure 1). The first testing session occurred two or three days after the initial visit to the laboratory, while the second testing session five or six days after the initial visit to the laboratory.

Anthropometric measurements. Body mass was measured with a manual weighing scale (Seca, Germany) and the stature on a standardized wall-mounted height board. We measured body composition by bioelectrical impedance analysis (Akern, Italy) using the software provided by the manufacturer (Bodygram,1.31).

Energy cost of running. We measured ventilation, oxygen consumption (V'O_2) and carbon dioxide production (V'CO_2) with a metabolic unit (K5, Cosmed, Italy) during the 10-minute running trial on a motorized treadmill (Saturn, HP Cosmos, Germany). Volume and gas analysers were calibrated before every trial as previously described.[17] Heart rate was measured with a dedicated device (Garmin, USA). Running trials that presented respiratory exchange ratio (RER) equal or higher than 1.0 would have been excluded from data analysis. However, none of the participants achieved RER values higher than 1.0 during the test. To compute the energy cost of running (in $J \cdot kg^{-1} \cdot m^{-1}$), data of the last two minutes of each trial were averaged. The Cr was then calculated from the ratio of the V'O_2 to the speed and then multiplied for an energy equivalent from 19.62 to 21.13, depending on the RER.[18]

Perceived Exertion. During the last minute of each running trial we asked the subjects to evaluate perceived exertion by using the Borg CR-10 Scale with the 0 value meaning "nothing at all" to 10 value meaning "extremely strong".[19] Similarly, we collected the pain perception during each SMFR exercise by asking to the subject to evaluate the perceived pain from 0 (no pain) to 10 (maximum pain).[20]

Maximal power and rate of force development during explosive lower limb extension. Peak power of the lower limbs was assessed during SJ and during CMJ by means of the Explosive-Ergometer (EXER), which was previously described elsewhere.[17] Briefly, the subject, sitting on a seat that is fixed to a carriage that is free to move on a rail, accelerates himself and the carriage seat backward by pushing on two force platforms (PA 300, Laumas, Parma, Italy). The velocity along the direction of motion is continuously recorded by a wire tachometer (SGI, Lika Electronic, Vicenza, Italy). The analog outputs of the force and velocity transducers are digitized and recorded by a data acquisition system (MP 100, Biopac). Power was obtained from the instantaneous product of the developed force (F, N) and the sledge velocity (*v*, m/s). We asked the participants to perform three SJ and three CMJ; the rest period between each jump was 3 minutes. The SJ and CMJ attempts with the highest peak power were considered for further analysis. In particular, we analysed the rate of force development (RFD) during the SJ and CMJ by assessing the force level every 50 ms from the onset of force development for 200 ms, expressing the force values as percentage of the maximal force exerted.[21] The onset of force development was determined by visual inspection of the force traces as well as by determining the moment in which the force value exceeded the mean baseline value plus 3 standard deviations.

SMFR treatment. The device used in this study to perform SMFR was BLACKROLL® Standard (BLACKROLL, Germany), with dimensions of 30 cm x 15 cm. This device was selected because of its smaller size, which makes transportation to training camps and competitions easier and it is largely used among professional athletes (as informally reported by an Olympic athlete). SMFR was applied on the following eight muscle groups of both limbs: plantar fascia, gastrocnemius, tibialis anterior, anterior thigh with extended knee, anterior thigh with flexed knee, posterior thigh, gluteus, fasciae latae. SMFR was performed under supervision of an expert physiotherapist. Each muscle group was treated for one minute;[14] the change in body position to treat a different muscle group took about 10 seconds. The pressure applied to the foam roller was self-selected; however, we instructed the participant to apply as much body mass as tolerable on the foam roller.[22] The application frequency was about 0.5 Hz (i.e. each rolling cycle lasted about 2 seconds).[23]

Statistical Analyses.

We analysed the data using PASW Statistic 18 (SPSS Inc., IL, USA) with significance set at $p \leq 0.05$. All results are reported as mean ± standard deviation (SD). Differences in Cr, lower limb muscle power and rate of force development collected at PRE, POST and POST 3h were studied with General Linear Model repeated measures with two factors considering ANOVA of the main effects of Condition (C: experimental condition *vs* control condition), Time (T: PRE *vs.* POST *vs.* POST 3h) and Condition x Time interaction. When significant differences were found, a Bonferroni post hoc test was used to determine the exact location of the difference.

RESULTS

Energy cost of running. Cr determined at PRE was very similar between the control and experimental conditions (6.55±1.52 and 6.32±1.61 J kg^{-1} m^{-1}, respectively, p=0.110). Also, in both conditions, the "Time" factor did not affect significantly Cr (Figure 2). However, in the experimental condition, Cr at POST tended to increase as compared to PRE (+6.2±8.3%, p=0.052), while at POST 3h Cr was restored to PRE values (+0.28±9.5%, p=0.950).

Maximal power of lower limb extensors and rate of force development. At PRE, the maximal power of lower limb extensors detected during SJ in the control condition was similar to that observed in the experimental condition (57.0± 10.2 W/kg and 54.9±14.6 W/kg, respectively, p= 0.471). Similarly, the maximal power measured during CMJ in the control condition was not different than that observed in the experimental condition (62.1±11.1 W/kg and 58.9±15.7 W/kg, respectively, p= 0.251). At PRE, in both conditions, the maximal power exerted during CMJ was higher than that exerted during SJ (+8.4±9.2%; $p<0.001$). Maximal power detected at POST and POST 3h in the control condition was not different than that observed at PRE for both SJ (p=0.741 and p=0.392, respectively, Figure 3A) and CMJ (p=0.750 and p=0.139, respectively, Figure 3C). In the experimental condition, no significant "Time" effect was observed for maximal power exerted during SJ, as power values similar to those assessed at PRE were found at POST (+4.5±7.8%, p=0.102) and POST 3h (+5.8±11.2%, p=0.139) (Figure 3B). On the other hand, maximal power exerted during CMJ at POST and POST 3h was significantly higher than that observed at PRE (+7.9±6.3%, p=0.002; and +10.0±8.7%, p=0.004, respectively) (Figure 3D).

The RFD measured during SJ was not different across PRE, POST and POST 3h time points in both conditions (p>0.05; Figure 4A and 4B). Similarly, peak force during SJ was not different between the control and experimental conditions (p=0.469; p=0.829 and p=0.907 at PRE, POST and POST 3h, respectively). On the other hand, RFD assessed during CMJ tended to increase right after the SMFR treatment (p=0.073 at 200 ms from the onset of force exertion), reaching a significant difference between PRE and POST 3h at 200 ms from the onset of force exertion (+38.9%, p=0.024, Figure 4D). These changes in RFD after SMFR treatment coincided with significant increments in peak force, which was 1819±362 N at PRE, 1925±548 N at POST and 1972±461 N at POST 3h (p= 0.177 between PRE and POST, and p=0.011 between PRE and POST 3h).

Perceived Exertion. In the control conditions the perceived exertion during the running trial at PRE was 2.7±1.2 and it was not different from the values registered at POST (2.8±1.1; p=0.723) and at POST 3h (2.8±1.1; p=0.586).

In the experimental condition, perceived exertion during the running trial at PRE was 2.6±1.1. This value was similar to those collected at POST (2.7±1.0, p=0.720), while it tended to be larger compared to that observed at POST 3h (2.2±0.9, p=0.054).

During SMFR treatment, the greatest pain was reported at the fascia latae (7.6±1.9), and the least pain at the plantar fascia (2.9±1.2). In addition, the other treated areas were scored as follow: gastrocnemius 4.5±1.6, tibialis anterior 5.5±1.2, anterior thigh with extended knee 5.1±2.1, anterior thigh with flexed knee 4.2±1.4, posterior thigh 3.5±1.8, gluteus 4.5±1.8.

Discussion

The present study showed that a 16-min SMFR treatment can acutely promote different motor output adaptations depending on the characteristics of the tested motor tasks. In particular, this intervention did not modify the maximal lower limb power exertion during explosive efforts without storage of elastic energy (SJ), improved the maximal power exertion during explosive efforts characterized by storage of elastic energy (CMJ), and tended to impair the energy cost of running (Cr) immediately after the intervention. The present study did not find any effect of SMFR on peak power during SJ, which can be considered a maximal explosive effort without storage of elastic energy involved. In particular, EXER does not allow any storage of elastic energy during SJ, as two mechanical blocks prevent any countermovement. Peak power exerted during SJ is primarily determined by the mass of lower limb extensor muscle chain, and particularly knee extensors, as well as by the muscle activation pattern.[24] It was previously shown that SMFR can induce neural adaptations, possibly inhibiting motor pools activation and altering the motor recruitment pattern, in response to pain receptors activation.[25] Seen as maximal power during SJ was not affected by SMFR, it is possible that neural-induced adaptations were limited in the present study, and/or that different motor pools were affected differently by SMFR according to the different pain level recorded across muscles (see Results). Hence, SMFR-mediated activation pattern adaptations may have counterbalanced neural inhibition and led to an overall lack of SMFR influence on power exertion during SJ.

CMJ was performed on the EXER removing the blocks, and thus allowing the carriage seat to move along the rail without restriction. Power output exerted during CMJ is influenced by the same physiological variables as SJ, with the addition of the elastic energy stored during the transition between eccentric and concentric phase. In the present study, we observed that peak power exerted during CMJ as well as RFD tended to increase immediately after SMFR application, and they further increased after three hours from SMFR application. The muscle mass, which affects lower limbs muscle power, is not altered by SMFR; hence, other physiological variables should be responsible for the changes observed in CMJ power output after SMFR. As reported above, it has been shown that SMFR can induce neural adaptations, possibly inhibiting motor pools activation and altering the motor recruitment pattern, in response to pain receptors activation.[25] Hodgson et al. reported that CMJ performance was not impaired after treatments that included the use of foam roller (by itself or in combination with static stretching), whereas it was negatively affected when the subjects underwent only static stretching.[3] It was then suggested that foam rolling may counterbalance the negative effects of static stretching on explosive performance.[3] The improvement in CMJ that we reported in the present study may be due to an improved storage and/or utilization of elastic energy, as a similar outcome was reported, for example, by Wilson et al. while investigating the effects of a flexibility training on rebound bench press vs. purely concentric bench press.[26] Also, Bradbury-squires et al. reported better efficiency while performing a lunge after foam roller treatment, suggesting that the same workload was performed with lower EMG activity because of a roller treatment-induced suppression of the H-reflexes.[14,25] Moreover, SMFR treatment-related nociceptive sensory input may have modified the muscle activation pattern, possibly improving the agonist-antagonist coordination and/or activation ratio during CMJ. Also, the increased RFD may be related to a better synchronization of motor units.[27] However, further studies that include the assessment of EMG activity should be performed in order to investigate neural-related adaptations due to SMFR during explosive efforts that include stretch-shortening cycles.

SMFR treatment can potentially also lead to an increased muscle compliance (i.e. lower muscle stiffness), and this adaptation can enhance the ability of the musculotendinous unit to store elastic energy.[28] SMFR can acutely alter viscoelasticity properties of the fascia (e.g.

shifting the balance between viscous and elastic proprieties more towards the latter) due to the prolonged rolling (one minute for each muscle) and the heat induced by the treatment may affect the muscle and tendon stiffness.[14] Indeed, the mechanical pressure and the heat following the roller massage may affect the fascia in two ways: 1) making the tissues soften and reducing their viscosity. And 2) remobilizing the fascia back to its gel-like state.[29] This last adaptation, however, could be maintained up to four hours from SMFR application.[15] It is plausible that these SMFR-induced adaptations on different tissues of the lower limb also contributed to an overall improvement in storage of elastic energy during maximal, explosive efforts of lower limbs that included a countermovement.

The energy cost of running tended to increase immediately after SMFR application ($p= 0.052$), thus impairing running performance.[30] It is plausible that this adaptation was related to the loss of water in the fascia, which could reduce the musculotendinous stiffness.[15] This decline in stiffness may affect the ability to store and release elastic energy during running.[31] In addition, the higher flexibility promoted by a SMFR treatment may have also negatively affected Cr, leading to greater energy expenditure for muscle stabilization.[6,9-11] However, the negative effects of SMFR treatment on Cr were not present after three hours form the treatment, as Cr returned to its initial value. It seems important to comment on the opposite acute effect that SMFR had on Cr and CMJ, as both running and CMJ performance are based, at least partially, on the storage of elastic energy. The stance phase, which comprises both eccentric and concentric phases, lasted on average ~300 ms, considering the mean speed equal to 11 km/h that the subjects maintained on average throughout the test.[32] Also, the knee angle during the stance phase ranged between about -15 and -45 deg (considering 0 deg the completed extension).[33] Conversely, CMJ push phase lasted between 500 and 600 ms, and the knee angle ranged between -80 and 0 deg. Also, we did not measure ground reaction forces during running; however, from the literature we can estimate peak forces during running of about 1.8 times the body weight (i.e. 1200 N).[32,34] On the other hand, peak forces exerted during CMJ were much higher (about 1900 N, see results). Finally, it is worth noting that CMJ was performed on a sledge ergometer, and hence the balance/stabilization component was negligible in this task. It seems possible that the acute effects of SMFR on gel-like state of the fascia and on the tissue viscosity, which conceivably leads to lower musculotendinous stiffness, may differently affect the recovery of elastic energy based on the amount of forces generated by the lower limb and on the movement duration and/or range of motion, favoring the storage of elastic energy when higher forces come into play. It is also interesting to note that both Cr and CMJ power exertion tended to improve at POST 3h compared to POST. This may suggest that rehydration of fascia and consequent increase in stiffness are of benefit for both high- and low-force motor tasks that involve storage of elastic energy.[15]

It is also important to note that the present findings are related to a single session of SMFR. It is possible that long-term SMFR application could affect Cr and lower limb power output in a different manner. For example, data related to static stretching showed that athletes who practiced stretching chronically obtained higher flexibility without affecting the energy cost of running.[35] Conversely, other authors reported that acute stretching can increase Cr because of a reduction of the mechanical efficiency of the lower body through the reduction of musculotendinous stiffness.[36]

Critique of methods

We acknowledge that our study has some limitations. First, the pressure that each subject applied to the foam roller was self-selected. Also, we did not directly measure the stiffness or water content of muscle and tendon tissues; thus, further studies are required to examine the effects of SMFR on these tissues. Finally, the lack of EMG activity recordings did not allow us to investigate in detail the effects of SMFR on neuromuscular activation characteristics.

Practical applications

The results of the present study suggest that an acute use of foam roller for SMFR performed immediately prior to running may negatively affect the endurance running performance. Conversely, performing SMFR treatment 3 hours before the running performance could be valuable because it would not alter Cr while promoting increased muscle power, which, in turn, may positively affect the running performance.[17] Also, conversely to other methodologies such as static stretching, SMFR may enhance the performance in athletic sports that include a high degree of elastic storage capacity (such as CMJ).

Conclusions

In conclusion, the findings of the present study demonstrate that an acute bout of foam rolling impairs the cost of running but it increases the power of the lower limbs when elastic energy is involved (CMJ). Athletes and coaches have to be aware of these results in order to use this tool when it is appropriate.

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FIGURE 1. Experimental design.

SMFR: self-myofascial release. Test Pre and Test Post: 10' running test + squat jump + counter movement jump

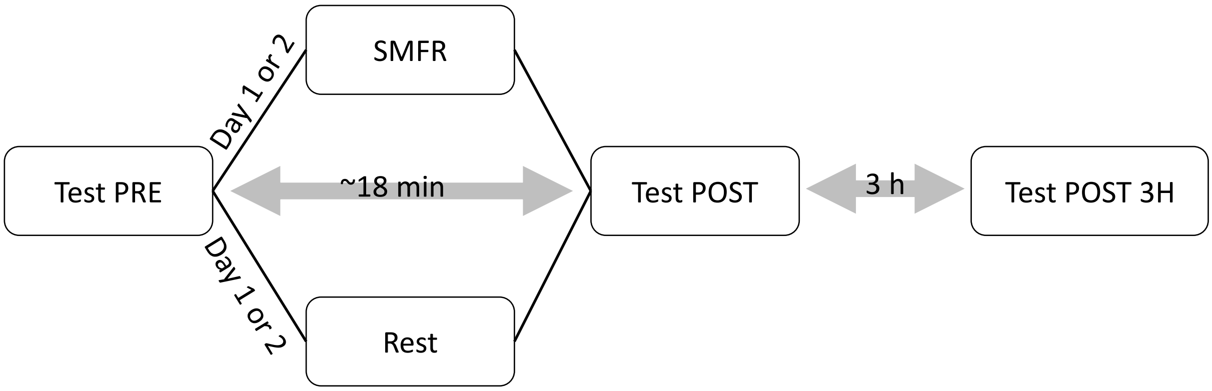
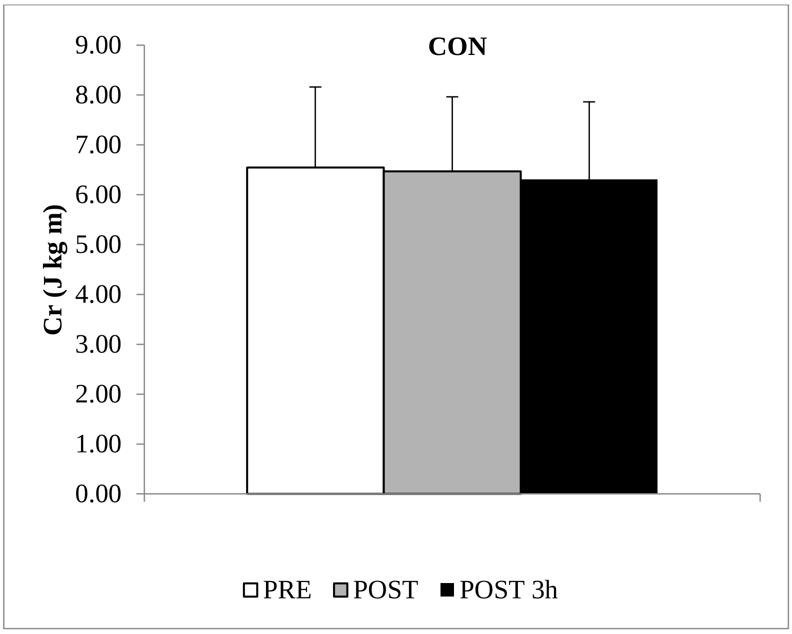


FIGURE 2. Energy cost of running ($J \cdot kg^{-1} \cdot m^{-1}$) measured before (PRE, white column), immediately after (POST, grey column) and 3h after the treatment period (POST 3h, black column) in control (CON, A) and experimental (EXP, B) condition.

A.



B.

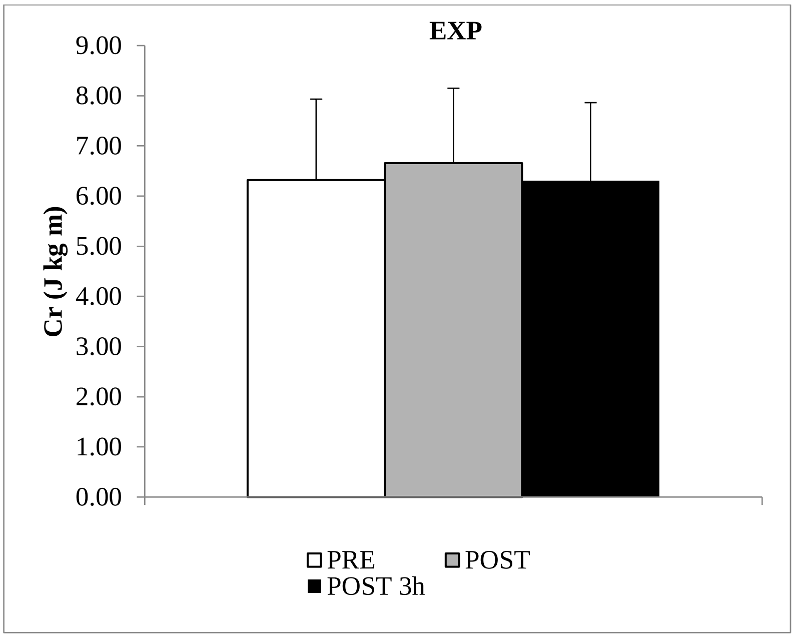


FIGURE 3. Squat jump peak power (SJ, W·kg^{-1}, Figure A and B^{-1}) and counter movement jump peak power (CMJ, W·kg^{-1}, Figure C and D) measured before (PRE, white column), immediately after (POST, grey column) and 3h after the treatment period (POST 3h, black column) in control (CON, A and C) and experimental (EXP, B and D) condition. *P<0.05

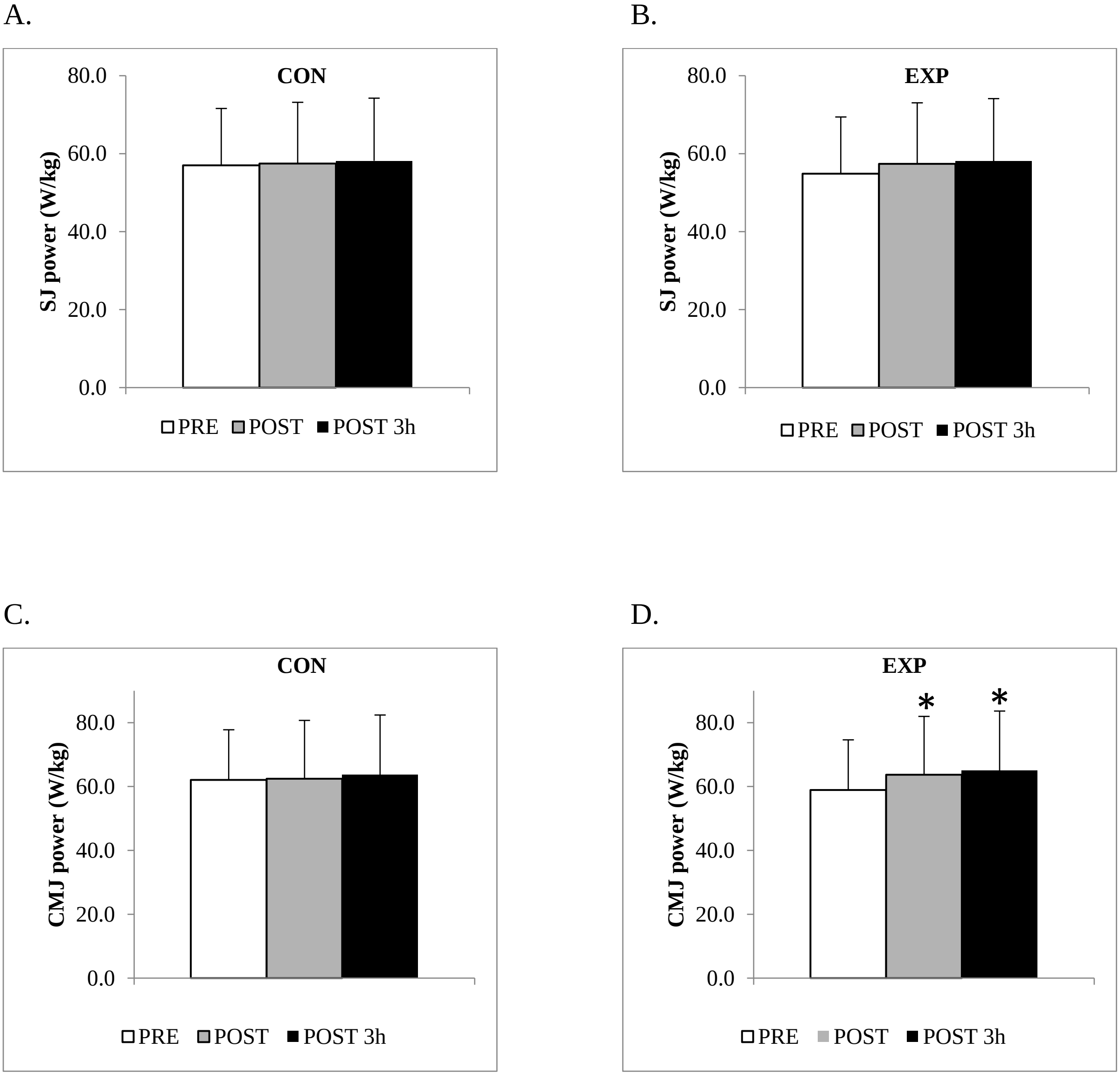


FIGURE 4. Rate of force development during explosive squat jump (SJ, in % maximal concentric force, Panels A and B) and counter movement jump (CMJ, in % maximal concentric force, Panels C and D) measured before (white circles) immediately after (POST, grey squares) and 3h after the treatment period (POST 3h, black triangle) in control (CON, A and C) and experimental (EXP, B and D) condition. *P<0.05

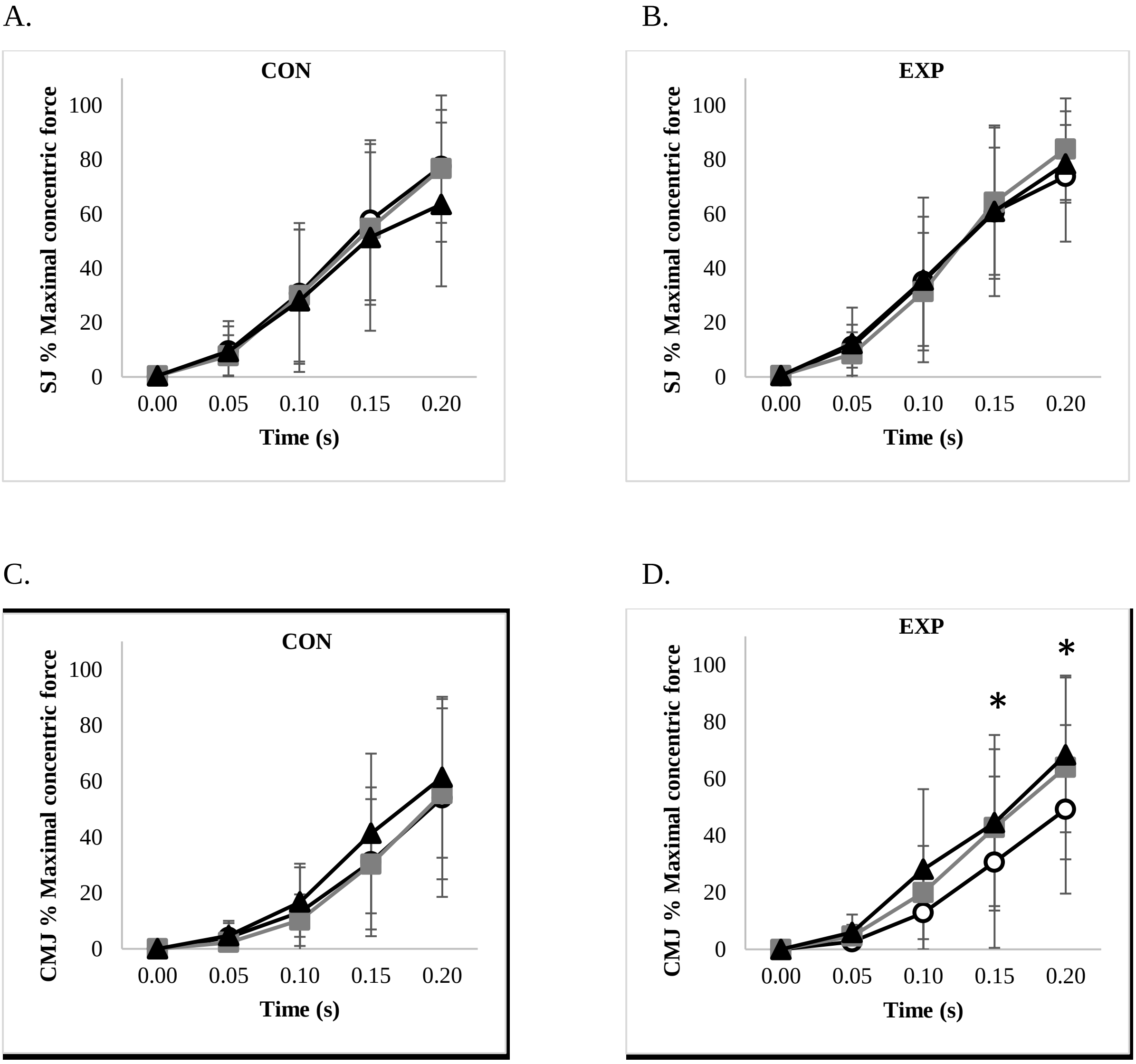


TABLE 1. Physiological characteristics of the subjects (n=13) and training status.

Age (y)	26.3	±	5.3
Stature (m)	1.80	±	0.06
Body mass (kg)	69.0	±	10.3
Fat mass (%)	16.5	±	7.7
Training status (hh/week)	9.9	±	3.5

All values are mean±SD.