Effect of Physical Methods of Lymphatic Drainage on Postexercise Recovery of Mixed Martial Arts Athletes

Aleksandra Zebrowska, PhD,* Robert Trybulski, PhD,*† Robert Roczniok, PhD,‡ and Wieslaw Marcol, PhD§

Abstract

Objective: Physical methods are reported to be important for accelerating skeletal muscle regeneration, decreasing muscle soreness, and shortening of the recovery time. The aim of the study was to assess the effect of the physical methods of lymphatic drainage (PMLD) such as manual lymphatic drainage (MLD), the Bodyflow (BF) therapy, and lymphatic drainage by deep oscillation (DO) on postexercise regeneration of the forearm muscles of mixed martial arts (MMA) athletes. **Design and Methods:** Eighty MMA athletes aged 27.5 ± 6.4 years were allocated to 4 groups: MLD, the BF device, DO therapy, and the control group. Blood flow velocity in the cephalic vein was measured with the ultrasound Doppler velocity meter. Maximal strength of the forearm muscles (Fmax), muscle tissue tension, pain threshold, blood lactate concentration (LA), and activity of creatine kinase were measured in all groups at rest, after the muscle fatigue test (post-ex) and then 20 minutes, 24, and 48 hours after the application of PMLD. **Results:** The muscle fatigue test reduced Fmax in all subjects, but in the groups receiving MLD, DO, and BF significantly higher Fmax was observed at recovery compared with post-ex values. The application of MDL reduced the postexercise blood LA and postexercise muscle tension. **Conclusions:** The lymphatic drainage methods, whether manual or using electro-stimulation and DO, improve postexercise regeneration of the forearm muscles of MMA athletes. The methods can be an important element of therapeutic management focused on optimizing training effects and reducing the risk of injuries of the combat sports athletes.

Key Words: strength training, fatigue, lymphatic system, physiotheraphy, muscle regeneration

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INTRODUCTION

Mixed martial arts (MMA) have emerged as a sport discipline relatively recently. The all-out and dynamic nature of MMA fights places high physiological demands on the contestants.[1] One reason for this is that the MMA rules allow the use of striking and grappling in both standing position and on the ground, and the combat itself involves many explosive actions such as kicking and striking, the effectiveness of which is often critical for the final result of a competition. The focus of training for combat sports, including MMA, is on building athletes' muscular strength and improving the dynamics of movements.[2,3] However, MMA is different from other martial arts, such that it requires high muscle strength endurance of the forearm muscles in the specific position of the hands protected by special gloves that provide grip and absorb strikes. The MMA fighters use fists and gripping of the opponents. Keeping the fists tight requires tight isometric muscle contraction, much stronger than that in boxing or other combat sports, and grips and submissions techniques involve alternate isometric contractions.[3,4]

Energy systems that an MMA fighter activates during a fight are the same as those enabling a repeated sprint effort. Early on, anaerobic processes increasing blood lactate and H^+ concentrations in the skeletal muscles play the main role, but their importance gradually decreases and toward the end of a fight the aerobic metabolism predominates.[1,5] High anaerobic capacity determines the ability to develop maximal power during short series of high-intensity exercises, but participating in MMA contests requires also high aerobic capacity and excessive oxygen consumption after exercise.[6,7] High oxygen consumption after physical exercise is responsible for the reestablishment of the muscular adenosine triphosphate and phosphocreatine stores, glycogen resynthesis, and blood lactate oxidation. Because concentric and eccentric muscle work during high-intensity efforts damages muscle fibers and leads to the release of markers such as creatine kinase (CK), lactate dehydrogenase (LDH), and myoglobin (Mb),[8–10] methods effectively supporting post-exercise recovery and accelerating muscle regeneration be an inherent element of sport training. One of key challenges in investigations of the periodization of MMA training is finding new therapies that could enhance its effects.[4]

There is evidence from research that doing aerobic exercises of moderate intensity after high-intensity resistance training effectively accelerates recovery processes.[11] Physical methods are reported to be important for expediting postexercise

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*From the *Department of Physiological and Medical Sciences, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland; †Department of Medical Sciences, The Wojciech Korfanty School of Economics, Katowice, Poland; ‡Department of Sports Theory, The Jerzy Kukuczka Academy of Physical Education, Katowice, Poland; and §Department of Physiology, Medical University of Silesia, Katowice, Poland.*

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Corresponding Author: Aleksandra Zebrowska, Department of Physiological and Medical Sciences, The Jerzy Kukuczka Academy of Physical Education, 72A, Mikołowska St, 40-065 Katowice, Poland (a.zebrowska@awf.katowice.pl).

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regeneration of the skeletal muscles and resynthesis of energy. Recent studies have found that the most effective are recovery methods improving blood circulation, filtration, and reabsorption in microcirculation, removing blood lactate and decreasing muscle soreness.[12–14] The elimination of blood lactate can be optimized by means of active recovery (at 30%-45% $\dot{V}O_2max$), massage, a combination of massage and active recovery, and manual lymph drainage. A major finding of earlier studies is that blood lactate as a marker of recovery is not directly implicated in muscle fatigue. However, a pH decrease associated with exercise-induced lactate production contributes to the development of muscle fatigue and so it may impede athlete's performance by inhibiting the activity of key glycolytic enzymes. Lactate removal from the blood is therefore an essential aspect of the recovery process and is crucial to the successful performance of repeated bouts of exercise.[15,16]

The physical methods of lymphatic drainage (PMLD) have been proven to effectively shorten postexercise recovery times in nonathletes and physically active persons.[12] Therapies accelerating lymph circulation, removing metabolic products, improving body fluid dynamics, and reducing activity of the adrenergic system seem particularly appropriate for upper extremity muscles performing static work during which increasing peripheral vascular resistance stimulates the adrenergic system, causing changes in microcirculation and reducing venous blood return.[17–19] The authors of studies on the effectiveness of lymphatic drainage therapies have also used different methods using mechanical stimulation (manual lymphatic drainage, MLD), mechanical and physical stimulation (deep oscillation, DO), and physical stimulation (BF). The different types of energy delivered by these methods provide an opportunity to assess the effectiveness of particular types of stimuli.

Manual lymphatic drainage improves lymphoangiomotoricity, collects lymph, and transports it to the lymph nodes.[17,20] Deep oscillation causes strong, resonant vibrations in tissues, thus improving lymph flows in the subcutaneous tissue and smooth muscles in the walls of lymphatic vessels. It has been confirmed to reabsorb edema, reduce pain, promote motoricity, improve trophicity and quality of the tissue, and to have anti-inflammatory and antifibrotic effects in the treatment of patients with acute sports injury and trauma.[21] Bodyflow (BF) therapy is an electric stimulation therapy that has been shown to facilitate lymphoedema management and increase venous velocity and blood flow.[22]

This study was designed to assess the effect of the PMLD such as MLD, electro-stimulation (the BF therapy), and lymphatic drainage by DO on postexercise regeneration of the forearm muscles of MMA athletes.

MATERIAL AND METHODS

Subjects

The sample consisted of 80 MMA athletes aged 27.5 ± 6.4 years, with an average training experience of 5.4 ± 2.2 years. The study participants were randomly allocated to 4 groups consisting of 20 persons each. Three groups were the treatment groups that received MLD therapy (MDL; n = 20), electro-stimulation with the BF device (BF; n = 20), and DO therapy (DO; n = 20). The fourth group was the control group (P; n = 20). Participants' body mass and body composition were determined from bioelectrical impedance analysis (BIA; InBody Data Management System, Biospace, Korea). The groups were not significantly different at baseline in the values of somatic variables selected for analysis ($P > 0.05$) (Table 1).

The exclusion criteria included broken continuity of the skin, inflammatory conditions of different aetiology, injuries to a motor organ, other conditions that could exclude an individual from the muscle fatigue test, as well as the use of drugs and doping substances.

The study was approved by the relevant Bioethics Commission (resolution no 1/2013 of June 22, 2013).

Procedure

In preparation for the study, the reaction of the superficial microcirculation and venous circulation in participants' forearms to PMLD was assessed (Table 2). To this end, the following types of PMLD were applied during 20-minute sessions:

1. Manual lymph drainage of the neck, the supraclavicular area and axillary lymph nodes, the elbow lymph nodes, and the forearm toward the bend of the elbow, according to the protocol developed by Dr Asdonk.[20]
2. Electro-stimulation with the BF device (Bodyflow International, Port Melbourne, Australia) using 4 electrodes distributed along the venous and lymph flow (6 ± 1 mA).
3. Deep oscillation (Physiomed Elektromedizin, Schnaittach, Germany) using a 5-cm diameter head (90 ± 10 Hz for the first 18 minutes and 50 ± 10 Hz for the remaining 2 minutes).

The use of physical methods in the control group (P) was simulated by irradiating the subjects' forearms with nontherapeutic light emitted by a laser scanner that made the same sounds as during real procedures.

As the sessions ended, blood flow velocity in the cephalic vein was measured in all participants with an ultrasound Doppler velocity meter (Ultrasonograf; General electric LogiQ, United Kingdom, 2008). The blood perfusion unit (PU) was calculated using data obtained with an Doppler ultrasound flowmeter (Perimed, Sweden, 2004) (Table 2).

The Protocol of the Muscle Fatigue Test

The maximal strength of the forearm muscles (Fmax) was measured in the participants with a manual hydraulic dynamometer (Baseline Evaluation Instruments, NY, 2013). Fmax values were then used to compute work intensity for the muscle fatigue test. The test required the participants to maintain an isometric handgrip force of 60% (±10%) of their maximal voluntary contraction force on the hydraulic handgrip dynamometer during a 5-second effort and 2-second rest cycle. Each participant performed 4 series of as many repetitions as they could at a given intensity. The rationale of the methods used to asses muscle fatigue was partly based on the experimental data presented by Vigouroux and Quaine.[23] Participants were seated for the test with the upper extremity flexed at the shoulder joint at 90 degree (±10 degree) and extended at the elbow joint. To prevent the fatigue of the synergistic shoulder girdle muscles, the extremity was supported. The duration of the test and handgrip force were controlled by the participants themselves (with a mirror for biofeedback). On the first day of the study, each participant performed the muscle fatigue test 4 times.

TABLE 1. Somatic Characteristics of the Exaimed Groups (Mean, SD)

Variable	DO	BF	P	MDH	F	P
Age, yrs	26.8 ± 5.6	27.2 ± 5.6	28.2 ± 7.3	27.7 ± 6.2	0.2	0.93
Body high, cm	179.8 ± 7.5	178.6 ± 6.0	178.2 ± 6.4	179.6 ± 6.5	0.3	0.84
Body mass, kg	78.4 ± 11.8	82.3 ± 11.7	83.6 ± 9.6	82.8 ± 8.1	1.1	0.36
BMI	24.3 ± 3.0	25.8 ± 3.0	26.4 ± 2.8	25.6 ± 2.0	2.1	0.11
Body fat, %	11.1 ± 4.4	13.7 ± 3.5	12.3 ± 5.7	11.6 ± 4.2	1.5	0.23
FFM, kg	69.2 ± 8.3	70.8 ± 9.1	69.7 ± 15.7	69.9 ± 14.5	0.1	0.98

BMI, body mass index; FFM, free fat mass; P, control group.

Participants were tested after a night's rest, 2 hours from the last meal and not earlier than 48 hours after physical exercise. These periods allowed fatigue-induced biochemical blood changes and biomechanical changes in the muscles to be measured. Participants did not do any other form of physical exercise over the length of the study.

Manual Lymphatic Drainage

After the muscle fatigue tests ended and blood samples were taken for biochemical analysis, participants received 30 minutes of MDL, BF, and DO therapies, respectively (see pts 1-3). The control group (P) was applied sham therapy consisting of 20 minutes of nontherapeutic laser scanner light. All procedures were repeated at the same time on study days 2 and 3.

Measurements

Maximal strength of the forearm muscles (Fmax), muscle tissue tension [represented by the area under the curve (AUC)], and pain threshold (PT) were measured in all groups at rest (*Rest*), after the muscle fatigue test (post-ex) and then 20 minutes (Rec20min), 24 hours (Rec24h), and 48 hours (Rec48h) after the application of physical therapies.

Fmax was measured with a handgrip test in standing participants who were instructed to squeeze the dynamometer as hard as they could for 5 seconds. Muscle tension was assessed in participants seating with the forearm rested on a support and flexed at the elbow joint at 90 degree. The head of the myotonometer probe (Neurogenic Technologies, Missoula, Montana, 2010) was pressed 8 times to a predetermined depth (millimeter) into a point on the palmaris longus muscle 10 ± 1 cm from the olecranon with a force gradually increasing from 0.25 to 2 kg. The AUC, a widely used measure of muscle tension, was calculated as a quotient of the amount of tissue deformation and the force applied by the myotonometer times the value of tissue displacement. A growing AUC points to decreasing surface tension of tissues.

Pain intensity was assessed with an algesimeter (Medical Industries, USA, 2011). Three measurements were made in each participant by pressing its probe into the selected point ($r = 4$ mm each time) on the palmaris longus muscle. The value of the force (kg or N) that was being applied when pain was reported was calculated as a mean of 3 trials. When the device signaled that measurements displayed excessive deviations, the procedure was repeated. Pain intensity was inversely related to PTs. The manner of performing all measurements (PT, AUC, Fmax) is shown in Figure 1.

Biochemical Testing

To determine the activity of CK, blood samples were taken from participants' basilic veins and analyzed using Randox reagents (CK-NAC) and the spectrophotometer UV-1202 (Shimadzu, Tokyo, Japan). Measurement accuracy was around 2.31 CV%. The capillary blood lactate concentration (LA) was measured with the Biosen CL_line analyzer (EKF Diagnostic, GmbH, Barleben, Germany). The range of measurement was 0.5 to 40 mmol/L and measurement accuracy (CV) ≤1.5% at 12 mmol/L. The testing procedures were performed as shown in Figure 1.

Statistical Analysis

The selected somatic variables were analyzed statistically by calculating their basic descriptive statistics such as measures of location and variability, and by testing them for normality of distribution with the Shapiro–Wilk test. To find out which means were significantly different, 1-way analysis of variance (ANOVA) and repeated-measures ANOVA were used. The significance of differences was assessed by the Tukey's post hoc multiple comparisons test with the level of significance set to $\alpha = 0.05$. Statistical analysis was performed using Statistica ver. 10. Graphics illustrating the results of analysis were produced with StatSoft, Inc, 2011.

TABLE 2. Blood Flow Velocity in the Cephalic Vein and Blood Perfusion Unit at Rest and Post Theraphy

Methods	Blood Flow Velocity in the Cephalic Vein, cm/s	Perfusion Unit (PU)
Rest flow	15.6 ± 2.3	11.8 ± 1.6
Deep oscillation	26.9 ± 2.9**	108.0 ± 5.3***
BF therapy	23.6 ± 3.0**	25.6 ± 3.0**
Manual lymph drainage	29.3 ± 2.9**	41.7 ± 3.6***

***P < 0.01, ***P < 0.001 significant differences rest flow versus therapy.*

RESULTS

The selected PMLD had a significant effect on blood flow velocity in the cephalic vein and the perfusion unit. In the groups receiving DO, MDL, and BF, the velocity was significantly higher than among controls. The influence of DO and MDL on the perfusion unit was advantageous and statistically very significant (Table 2; $P < 0.001$ in both cases).

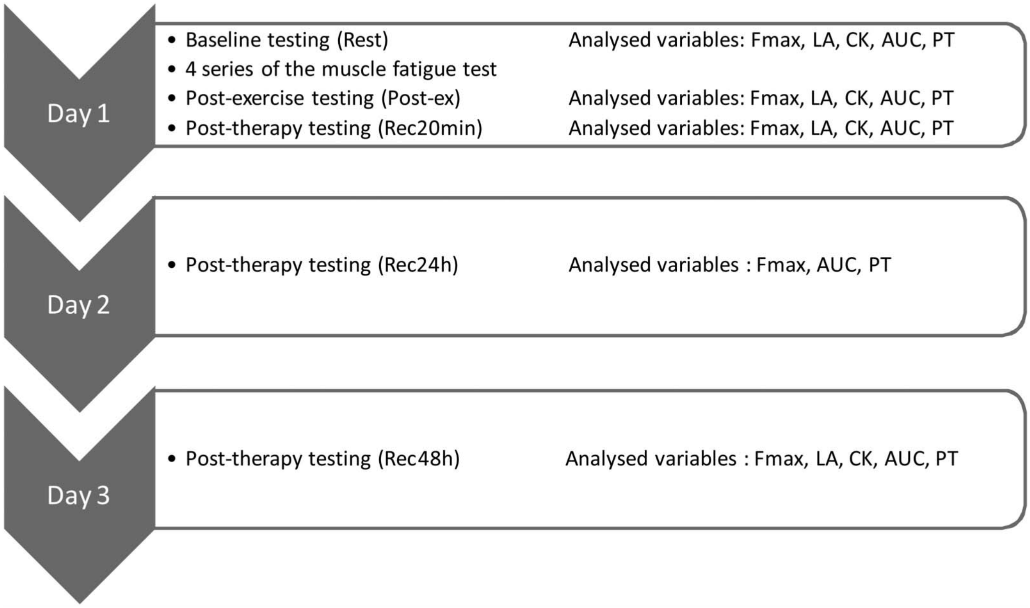

Figure 1. The manner of analyzing the selected variables.

Muscular Strength

The handgrip strength test showed that forearm strength did not differentiate participants before physical therapies were applied (Fmax Rest; $P > 0.05$). The muscle fatigue test reduced Fmax (post-ex) in all 4 groups, but in the groups receiving MDL, DO, and BF its values rose to be significantly higher at Rec20min, Rec24h, and Rec48h than post-ex (Figure 2A). Fmax values recorded in the control group (P) post-ex and in the period of recovery were not significantly different. At Rec20min, Rec24h, and Rec48h, they were statistically significantly lower than in the other 3 groups (Figure 2B).

Pain

The application of PMLD significantly reduced the effect of postexercise muscle fatigue on PT (Figure 3A). The muscle fatigue test caused muscle soreness in all participants, a proof of which was statistically significantly lower PTs after exercise (post-ex) than at rest (Rest). Physical therapies significantly raised PTs above levels noted after the muscle fatigue test. In the control group, PTs at Rec20min, Rec24h, and Rec48h were lower than after exercise (post-ex), significantly differentiating controls from the MLD, DO, and BF groups (Figure 3B).

Muscle Tension

The muscle fatigue test had a significant effect on muscle tension (ie, AUC) in all 4 study groups ($P < 0.001$) (Figure 4A). The combined effect of a physical therapy and the length of recovery on the size of AUC was found to be significant ($F = 18.0$; $P < 0.000$). Area under the curve established after exercise was significantly smaller for all

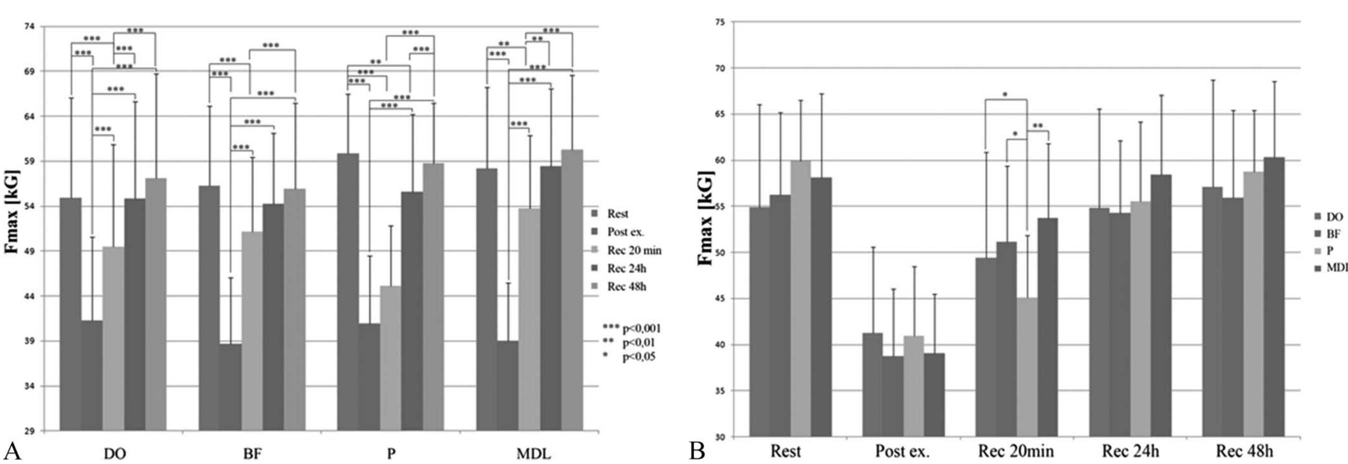

Figure 2. A and B, Maximal strength of the forearm muscles (Fmax) at rest (rest), after the muscle fatigue test (post-ex) and 20 minutes (Rec20min), 24 hours (Rec24h), and 48 hours (Rec48h) after the application of physical therapies.

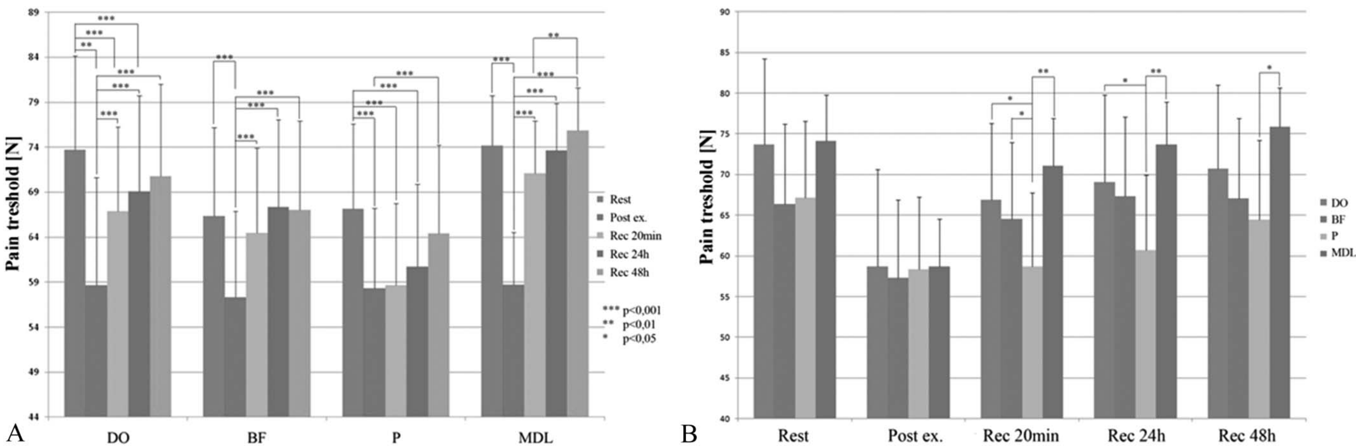

Figure 3. A and B, Pain threshold at rest (rest), after the muscle fatigue test (post-ex) and then 20 minutes (Rec20min), 24 hours (Rec24h), and 48 hours (Rec48h) after the application of physical therapies.

participants, but at Rec20min, Rec24h, and Rec48h it was statistically significantly greater than after exercise in the groups receiving MDL, DO, and BF. In the control group, it was only at Rec48h that a significant increase in AUC (in relation to its post-ex value) was noted (Figure 4B).

Biochemical Indicators

Blood LAs measured after the application of DO, BF, and MDL were significantly lower from those established after exercise ($P < 0.001$) (Figure 5A). In the control group, LA levels noted at Rec20min and after exercise were not significantly different ($P > 0.05$). This implies that passive recovery is unable to reduce blood LA. After the application of MDL, LA decreased by Rec20min to its rest value (Figure 5B).

Blood CK activity levels measured after exercise and at rest were not statistically significantly different. The DO and MDL groups were the only ones with CK activity lower at Rec48h than post-ex and at Rec20min (Figure 6A, B).

The analysis of variance showed that the selected physical methods had a significant effect on PT ($F = 4.32$; $P < 0.007$) and blood LA ($F = 10.98$; $P < 0.001$).

DISCUSSION

In this study, the effect of PMLD on postexercise muscle regeneration in MMA athletes was determined by analyzing variables characterizing the ability of muscles to work and generate maximum power. One of its main findings is that in the first phase of postexercise recovery (Rec20min), the selected PMLD increased maximal strength of the forearm muscles while reducing their tension. This indicates that they can be used to enable an athlete to perform repetitive efforts.

The indirect, positive effects of PMLD were evaluated by comparing muscle tension measurements obtained through myotonometry, a noninvasive method producing results comparable with EMG readings, which is effectively used to estimate the tension of muscular and subcutaneous tissue. According to the results of earlier reports, myotonometric measurements are not significantly different from those yielded by superficial electromyography.[24]

Participants' PTs were determined by measuring pressure PTs. This approach allows an objective assessment of PT at rest, as well as its changes after the application of therapeutic methods such as lymphatic drainage used in this study.

The subjective feeling of muscle soreness reported by participants was significantly lower immediately after the

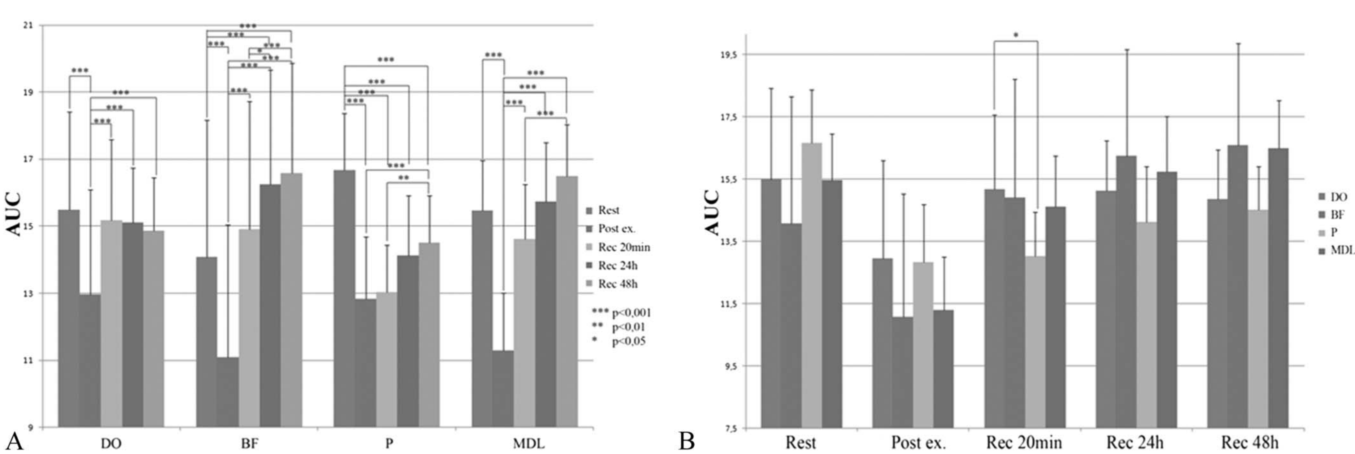

Figure 4. A and B, Muscle tissue tension (AUC) at rest (rest), after the muscle fatigue test (post-ex) and then 20 minutes (Rec20min), 24 hours (Rec24h), and 48 hours (Rec48h) after the application of physical therapies.

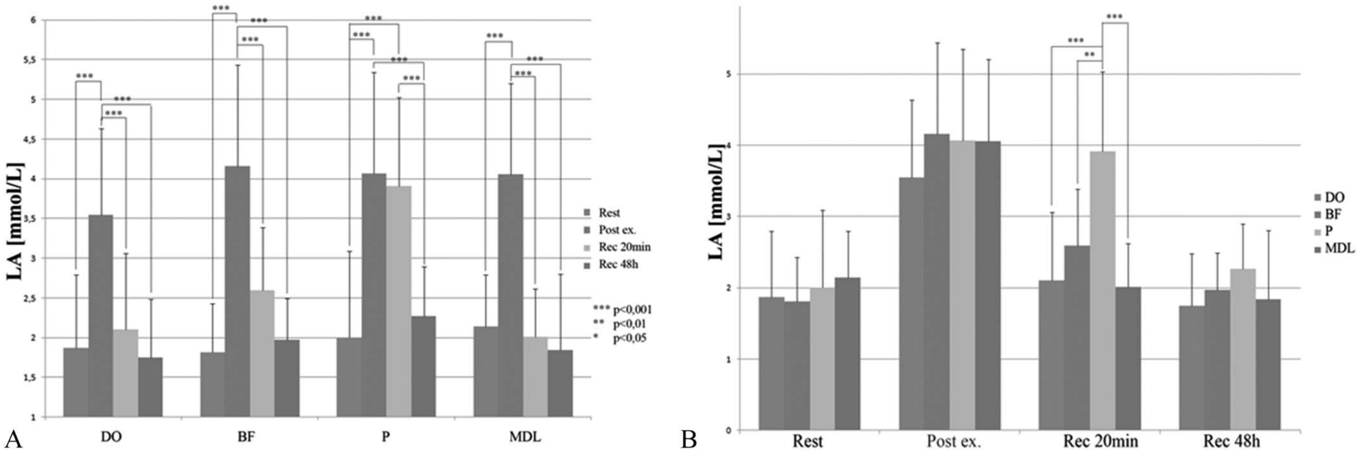

Figure 5. A and B, Blood LAs at rest (rest), after the muscle fatigue test (post-ex) and then 20 minutes (Rec20min) and 48 hours (Rec48h) after the application of physical therapies.

application of a PMDL (Rec20min) but also 24 hours later (Rec24h). This outcome seems very important, because research evidence clearly indicating that PMDL can facilitate postexercise muscle regeneration in combat sports athletes has not been presented so far. However, there are well-documented reports concluding that being successful in combat sports depends on the appropriate intensity of physical effort and rest that enables an athlete to repeatedly perform physically at the highest level.[1,3,5,25]

Mixed martial arts that have recently become very popular across Europe are distinctly different from other combat sports regarding the level and type of training loads.[2,4,7] The focus of modern training for MMA is on building muscle, tendon, and ligament strength, as well as on functional benefits such as increased speed of movements, improved joint function, and the prevention of injuries. The combination of muscular strength and speed of movements is called dynamic strength.[6] The duration of MMA fights, particularly during championships, requires that the contestants have high endurance capabilities that depend on a high proportion of anaerobic muscle fibers to total body mass and fast recovery from intramuscular changes after exercise. Short breaks between the rounds have negative effect on blood lactate oxidation, the kinetics of muscular adenosine triphosphate, phosphocreatine, and glycogen resynthesis and on the mitigation of the impact of high-intensity physical effort—in some athletes they can even delay the onset of muscle soreness.[17,26,27]

The local regulation of blood flow and improving blood outflow from exercising muscles are reported to significantly contribute to the regeneration of the skeletal muscles.[12,28,29] In physiological conditions, blood flow disorders in the upper extremities are incomparably smaller those than in the lower extremities, but the disproportion between the muscle mass of the upper extremities and the density of their capillaries may lead to vascular resistance disturbing blood flow velocity and the removal of the waste products of cellular metabolism.[18,30]

The influence of humoral factors on local blood flow regulation is well documented.[18,30–32] Having analyzed blood flows in exercising forearm muscles, Green et al[18] (2002) reported that vasoconstrictive substances have an important role in vascular adaptation to static exercise. All the studies confirm that PMLD can contribute to the correct circulation of vasoconstrictive substances in blood and lymphatic vessels. What role the lymphatic system exactly plays in muscle

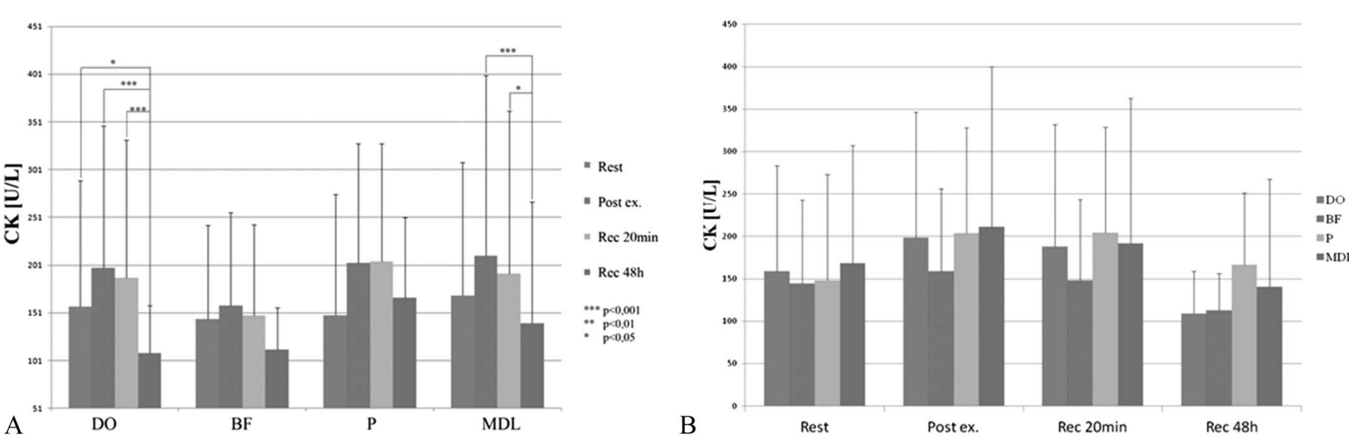

Figure 6. A and B, Creatine kinase activity at rest (rest), after the muscle fatigue test (post-ex) and then 20 minutes (Rec20min) and 48 hours (Rec48h) after the application of physical therapies.

adaptation to exercise and postexercise regeneration has not been fully explained yet, but available studies indicate that changes in microcirculation are important for adaptation to exercise over a 12-months' training cycle. Research results suggest that the intensity with which the lymphatic system responds to exercise varies with time and that its role, the biggest in the first phase of exercise, decreases with increasing reabsorptive function of venous capillaries.[33] The stimulation of the lymphatic system mainly leads to leucocytosis and greater numbers of neutrophilic granulocytes, lymphocytes, and anti-inflammatory cytokines in blood, probably because of higher outflow of lymph from the lymph nodes.[34,35]

Increased velocity of venous blood flow and microcirculatory perfusion reported by other authors as well as faster blood flow in the cephalic vein and higher perfusion unit obtained in this study suggest that supporting the function of the lymphatic system can significantly improve training effects.[19,34–36]

It is also noteworthy that the selected physical methods increased blood flow in the treated muscles, so they can improve microcirculatory filtration and reabsorption and consequently, expedite the removal of metabolic products from muscles after exercise. Increased blood flow in the cephalic vein and higher perfusion unit noted in all groups receiving physical therapies, as well as an inverse relationship between blood LA and the perfusion unit in the MDL group, point out that the therapies were effective. This conclusion is underpinned by the results of laser Doppler flowmetry, a repeatable, sensitive, and noninvasive method enabling precise measurements of microcirculatory responses to physical stimuli. Let us note, however, that the perfusion unit was used in the study only to compare changes in microcirculatory perfusion caused by particular physical methods and not for diagnostic purposes.[37]

The importance of the lymphatic system derives from the lymph fluid's ability to move between the deep and superficial components of the system.[38] Electro-stimulation and/or manual massage applied to the superficial component cause more lymph flows to it from the deep component and indirectly stimulate lymphoangiomotoricity in the skeletal muscles.[35]

Reports concluding that there are no clear indications for using lymph drainage in sport[39] and those pointing out that MDL can reduce the levels of muscle fatigue markers and inflammatory enzymes and influence the composition of lymph fluid[14] are underpinned by the detailed analyses of capillary filtration and capillary reabsorption processes. There is evidence that in addition to boosting lymphatic circulation, MDL reduces blood LA and increases oxygen transport to the muscles. A significant reduction of blood LA and LDH activity has been noted immediately after the application of MDL,[34] as well as 2 hours[12] and 48 hours[14] later. The meta-analysis Vario et al[39] (2009) have conducted failed to find scientifically valid reports on the use of MLD for enhancing training effects and regeneration processes in athletes. One of the main conclusions of this study that offers a novel approach to presenting the effects of different PMLDs is that the effects need to be considered with respect to the phase of the recovery period.

In this study, to find out how PMLD influences muscle fatigue markers, blood LA and CK activity obtained after exercise and lymphatic drainage procedures were compared between the treatment groups and the control group. Both these parameters are useful in assessing what part of the skeletal muscle metabolism is due to glycolytic processes, the amounts of mechanical myocyte stress and peripheral fatigue, and/or muscles' ability to cope with postexercise changes.[6,9,30] It is well evidenced that blood lactate is not implicated in muscle fatigue; however, lactate removal from the blood has been shown to be an essential aspect of the recovery process and crucial to the successful performance of repeated bouts of exercise.[16,40]

All physical therapies [MLD, DO, and electro-stimulation (BF)] were found to effectively reduce blood LA in the first phase of postexercise recovery (Rec20min), but the reduction of CK activity was not significant compared with that noted among untreated controls.

Another innovative and important aspect of this study is that it evaluates the effects of stimuli produced by lymphatic drainage therapies using mechanical stimulation (MLD), mechanical and physical stimulation (DO) and physical stimulation (BF). The different types of energy used provided an opportunity to assess the effectiveness of particular types of stimuli.[21,22]

The study has demonstrated that the lymphatic drainage methods significantly change influence threshold and blood LA, and that MDL accelerates postexercise regeneration of the forearm muscles of the MMA athletes more than DO and BF.

Notwithstanding the fact that the methods and agents used in support of physiological regeneration are considered an important element of training periodization,[8,11,41] the efficacy with which they assist the adaptation of microcirculation in athletes is not fully known yet.[18,24,27,28,42]

Manual lymphatic drainage is based on the elastic deformation of cutaneous and subcutaneous tissues. The procedure has 2 phases: one causes lymph fluid to move and improves lymphoangiomotoricity and the other aims to collect lymph and transport it to the lymph nodes.[17,20] MDL has been demonstrated to statistically significantly increase muscular strength and eliminate blood lactate in the muscles immediately after exercise.[12] This study has shown that MDL was the most effective in reducing muscle soreness immediately after application and 48 hours after the muscle fatigue test.

Deep oscillation causes strong, resonant vibrations in tissues that are alternately pulled and released by electrostatic forces operating within a range of 5 to 250 Hz. Its protocol follows the rules of lymphatic drainage developed by Dr. Asdonk.[20] Deep oscillation is effective because the interference between mechanical and electrostatic stimuli improves lymph flows in the subcutaneous tissue and smooth muscles in the walls of lymphatic vessels.[21] In this study, DO proved effective in the first phase of postexercise recovery (Rec20min), because it increased muscular strength while reducing pain level, blood LA and muscle tension. Similar changes were not observed in the control group.

The third physical method selected for this study (electro-stimulation with the BF device) increases venous and lymphatic peristalsis by stimulating smooth muscles between 2 contact electrodes delivering low-frequency electrical current.[22,43] In this study, electro-stimulation of smooth muscles between the wrist and the arm pit in the direction following blood and lymph flows was proved to have a particularly significant effect on improving muscle strength and reducing postexercise muscle tension (smaller AUC).

We concluded that the usefulness of therapeutic massage for preventing muscle fatigue and reducing the levels of fatigue markers has already been confirmed by earlier research, but this study is the first one to demonstrate that lymphatic drainage methods can be of use for combat sports athletes.

Practical Applications

Physical methods of lymphatic drainage, whether manual or using electro-stimulation and DO, significantly improve post-exercise regeneration of the forearm muscles of MMA athletes. Supporting the venous and lymphatic systems is the most important in the first phase of recovery. The results of this study on the role of PMLD in reducing fatigue symptoms show that the methods can be an important element of therapeutic management focused on optimizing training effects and reducing the risk of injuries of the combat sports athletes.

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