

# The Effect of Deep Tissue Massage on Lactate Clearance Kinetic and Muscle Strength Recovery

*Maksym Vlasov*

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**Annotation. Relevance of the study.** The relevance of this study is determined by the increasing intensity and density of training and competitive loads in modern sport, which significantly raise the requirements for effective post-exercise recovery. One of the key physiological markers of muscular fatigue is lactate accumulation, the clearance kinetics of which are closely associated with the restoration of muscle strength and readiness for repeated physical efforts. Despite the widespread use of deep tissue massage in sports medicine and physical therapy, its effects on lactate clearance dynamics and functional muscle recovery remain insufficiently systematized and require experimental justification.

**Purpose of the study.** The purpose of this article was to experimentally determine the effect of deep tissue massage on blood lactate clearance kinetics and the recovery of muscle strength after intense physical exercise in order to substantiate effective approaches to optimizing recovery interventions in sport and physical therapy.

**Methods.** The study was conducted as a controlled comparative experiment with repeated measurements. A standardized high-intensity exercise protocol was applied, followed by recovery either with deep tissue massage or passive rest. Blood lactate concentration and muscle strength indicators were assessed at fixed time points during the post-exercise period. Experimental conditions, testing procedures, and recovery protocols were standardized to ensure the reliability and objectivity of the results.

**Results.** It was established that the application of deep tissue massage was associated with a faster reduction in blood lactate concentration during the early post-exercise recovery period compared with passive rest. It was demonstrated that accelerated metabolic recovery was accompanied by higher rates of muscle strength restoration within 10–30 minutes after exercise. A time-dependent specificity of the massage effect was identified, indicating its functional relevance for subsequent physical performance.

**Conclusions.** The findings indicate that deep tissue massage is an effective post-exercise recovery modality influencing not only subjective fatigue perception but also objective metabolic and strength-related parameters. The feasibility of its selective and individualized application depending on the characteristics and intensity of physical loads was substantiated.

**Prospects for further research.** Further studies should focus on clarifying dose-dependent effects of deep tissue massage, developing objective criteria for controlling mechanical stimulation intensity, and investigating the long-term influence of massage on adaptive processes and the stability of muscular performance.

**Keywords:** post-exercise recovery, muscular fatigue, metabolic clearance, physical therapy, manual interventions, functional performance, sports rehabilitation.

### **Вплив глибокого масажу тканин на кінетику виведення лактату та відновлення м'язової сили**

**Анотація.** Зростання інтенсивності тренувальних і змагальних навантажень потребує застосування науково обґрунтованих засобів післянавантажувального відновлення. Лактат є основним біохімічним маркером м'язової втоми; його виведення з крові корелює з відновленням м'язової сили та функціональної працездатності. Мета дослідження – експериментально визначити вплив глибокого масажу тканин на динаміку виведення лактату з крові та відновлення м'язової сили після інтенсивних фізичних навантажень. Дослідження проведено як контрольований порівняльний експеримент із повторними вимірюваннями. Концентрацію лактату в крові та показники м'язової сили вимірювано у фіксовані часові інтервали після навантаження під час застосування глибокого масажу тканин і пасивного відпочинку. Виявлено, що глибокий масаж тканин прискорює зниження концентрації лактату та відновлення м'язової сили у ранньому післянавантажувальному періоді порівняно з пасивним відпочинком. Доведено доцільність індивідуалізованого використання глибокого масажу тканин як ефективного засобу післянавантажувального відновлення.

**Ключові слова:** післянавантажувальне відновлення, м'язова втома, метаболічний кліренс, фізична терапія, мануальні методи, функціональна працездатність, спортивна реабілітація.

### **Introduction**

With the increasing intensity of training and competitive loads in modern sport, the issue of accelerated and scientifically grounded restoration of the functional state of the muscular system after substantial physical exertion has become increasingly relevant. One of the key physiological indicators of muscle fatigue is lactate accumulation, the dynamics of its production and clearance being directly associated with the effectiveness of recovery processes, the restoration of muscle strength, and the athlete's readiness for repeated physical effort. Despite the widespread application of massage in sports medicine and physical therapy, the effects of deep tissue massage on lactate clearance kinetics and the recovery of muscle strength characteristics remain controversial and insufficiently systematized from the perspective of modern physiology and evidence-based medicine. The practical importance of this issue arises from the need to optimize recovery strategies in sports training, prevent overload, and reduce injury risk, particularly under conditions of intensive training schedules and multi-day competitions. From a scientific perspective, investigating the effects of deep tissue massage on lactate clearance rates and muscle strength recovery contributes to a deeper understanding of the mechanisms underlying the interaction between mechanical manual interventions and microcirculatory, metabolic, and neuromuscular regulatory processes. Identifying objective patterns within these processes is essential for the development of standardized and differentiated physical therapy protocols adapted to specific sports demands, training levels, and athletes' functional states, thereby emphasizing the close relationship of the present problem with current research priorities in sports physiology, rehabilitation medicine, and performance recovery practice.

An analysis of current scientific literature indicates the gradual development of a comprehensive understanding of massage as a physiologically grounded modality for post-exercise recovery. In a study by D. Arsovski, deep tissue massage is considered a factor in enhancing muscle performance and athletic productivity through combined mechanical effects on tissues and systemic regulatory responses [1]. Croitoru I. et al. examine the post-exercise

recovery process in a broader context, emphasizing massage as a fundamental element of regeneration alongside rest and physical therapy [2]. Kalaycioglu T. et al. focus on the significance of physical therapy and massage procedures for maintaining muscle strength and adapting to training stress, providing a theoretical foundation for analyzing post-exercise lactate concentration changes [3].

A substantial body of research is dedicated to experimental evaluation of massage effectiveness compared to other recovery strategies. Budak H. demonstrates that sports massage produces faster reduction in blood lactate levels compared to passive rest following high-intensity exercise [4].

Adane A. analyzes various recovery modalities following maximal anaerobic exercise, revealing significant differences in lactate clearance kinetics depending on the type of recovery intervention [5]. Haryono T. and colleagues investigate the time course of lactate recovery in athletes after sports massage, confirming its ability to shorten the duration of the metabolic recovery phase [6].

A separate body of research examines the effects of different massage techniques and combined procedures on muscle function and strength parameters. Kablan N. and colleagues compare the effects of petrissage and manual lymphatic drainage after exercise, noting differences in the viscoelastic properties of muscle tissue, which are important for strength recovery [7]. Chaiyakul S. and colleagues analyze the combination of cold water immersion with Swedish massage, demonstrating a positive effect on lactate levels, muscle strength, and exercise performance indicators [8]. Li H. and colleagues evaluate percussion massage therapy for delayed-onset muscle soreness in a randomized controlled trial, enabling distinction between metabolic and structural-functional aspects of strength recovery [9].

Alongside physiological aspects, the individualization of recovery and the role of psycho-emotional and digital factors are receiving increasing attention. Zhaivoronok A. considers body-oriented practices as a form of psychological support that indirectly affects the subjective perception of recovery after exercise [10]. Tatmurzinova Y. proposes an original psychological tool for transforming resource identity, highlighting the importance of the psycho-emotional component in recovery processes [11]. Divel M. examines applied art in post-rehabilitation support, underscoring the multidisciplinary nature of recovery [12]. Tkachenko D. demonstrates differences in the dynamics of resource recovery according to personality type, supporting the need for personalized recovery programs [13]. Smorshchok M. and Stetsenko T. investigate aesthetic and digital approaches, including the use of artificial intelligence, in predicting responses to therapeutic interventions [14–15].

Despite existing studies on post-exercise recovery, the effects of deep tissue massage on lactate clearance kinetics and muscle strength recovery remain insufficiently understood. Uncertainty persists regarding the temporal dynamics of its action, optimal dosage, and the combined assessment of metabolic and functional effects within a single experimental design, which limits the practical interpretation of available findings.

The proposed study addresses these gaps by experimentally integrating the assessment of blood lactate concentration and muscle strength during the post-exercise period. This approach makes it possible to clarify the practical effects of deep tissue massage and to develop scientifically grounded recommendations for its application in sports and physical therapy.

The purpose of this article is to experimentally determine the effects of deep tissue massage on lactate removal kinetics and muscle strength recovery following intense physical exertion in order to enhance the effectiveness of recovery interventions in sports and physical therapy.

To achieve this objective, the article addresses the following tasks:

1. Analyze the physiological mechanisms of muscle fatigue and post-exercise recovery with consideration of lactate dynamics.

2. Experimentally evaluate the effects of deep tissue massage on metabolic and strength recovery indicators.
3. Substantiate the scientific and practical rationale for the use of deep tissue massage in physical therapy and sports recovery.

### Results

The accumulation of lactate during intense muscular activity is a direct consequence of the predominance of anaerobic energy supply mechanisms under conditions of high contraction velocity and limited aerobic capacity. Elevated lactate concentrations are associated with alterations in acid-base balance, reduced efficiency of neuromuscular transmission, and deterioration of the contractile properties of muscle fibers, leading to the development of functional fatigue. During the post-exercise period, lactate becomes integrated into restorative metabolic processes, and the rate of its elimination is determined by the intensity of blood circulation, the activity of oxidative pathways, and the functional state of regulatory mechanisms (Table 1).

Table 1

Physiological features of lactate accumulation and elimination during physical exertion and recovery

Phase of muscle activity	Dominant metabolic processes	Functional manifestations	Significance for recovery
Intense exercise	Anaerobic glycolysis, increased lactate production	Increased lactatemia, decreased muscle pH, decreased strength	Formation of metabolic fatigue
Early recovery period	Transport of lactate from muscles into blood, partial oxidation	Decrease in metabolic acidosis	Initial recovery of contractile function
Late recovery period	Oxidation of lactate, gluconeogenesis	Normalization of metabolic status	Complete restoration of working capacity

*Source: compiled by the author based on [1; 2; 6, p. 190; 10, p. 1940]*

In modern sports practice, lactate is regarded not as a passive by-product but as a dynamic indicator of exercise intensity and recovery efficiency. In the training process of athletes engaged in speed-strength and cyclic sports, lactate monitoring is used to assess load adequacy and to determine the optimal duration of rest intervals. For example, in multi-series sprinting or interval protocols, delayed lactate elimination is associated with a progressive decline in peak muscle strength and coordination, which increases the risk of technical errors and overload. During the post-exercise period, the acceleration of blood flow and microcirculation is critical for the transport of lactate from active muscles to organs where it is utilized. In practice, this process is achieved through a combination of passive rest and targeted recovery interventions that modulate vascular and neuromuscular responses [3, p. 535]. For athletes performing repeated starts within short time intervals, particularly in team and combat sports, the rate of transition from the early to the late phase of recovery determines readiness for subsequent loads and the preservation of strength indicators [12, p. 1907]. From a physical therapy perspective, understanding lactate elimination kinetics enables the individualization of recovery programs according to the athlete's training level and functional state. In practical terms, this approach allows for an informed selection of the timing, duration, and intensity of manual and movement-based interventions to stimulate metabolic recovery

without imposing excessive additional stress on the fatigued muscular system, which is essential for maintaining stable athletic performance.

Deep tissue massage is regarded as a targeted mechanical intervention on muscular and fascial structures that exerts its effects through a combination of vascular, metabolic, and neuromuscular regulatory mechanisms. Unlike superficial techniques, deep tissue massage is directed toward altering the mechanical properties of soft tissues, reducing localized tension, and restoring the mobility of muscle fibers and fascia. These effects create conditions for reflexive and local reorganization of blood circulation, optimization of metabolic processes, and normalization of the functional state of the neuromuscular apparatus without direct interference in the training process (Table 2).

Table 2

## Mechanisms of deep tissue massage on the functional state of skeletal muscles

Direction of influence	Physiological mechanism	Functional effect	Significance for recovery
Blood circulation and microcirculation	Mechanical stimulation of the vascular bed, reduction of tissue pressure	Increased regional blood flow, improved venous outflow	Acceleration of oxygen and nutrient delivery
Metabolic processes	Activation of metabolite transport, reduction of stagnation	Optimization of local metabolism	Increased recovery efficiency
Neuromuscular function	Effect on proprioceptors and muscle tone	Reduction of hypertonicity, improvement of contraction coordination	Restoration of motor control

*Source: compiled by the author based on [2; 3, p. 531; 5, p. 7; 7, p. 727; 11, p. 1170]*

The interrelationships among the mechanisms presented in Table 2 indicate the systemic nature of the effects of deep tissue massage on the functional state of skeletal muscles. Mechanical воздействие on muscle and fascial structures reduces local tissue resistance and promotes the redistribution of blood flow in areas subjected to increased functional load. This creates conditions for the normalization of regional blood circulation in muscle groups exposed to prolonged or repeated contractions, particularly in the muscles of the lower extremities during cyclic loads or in the proximal segments of the upper extremities in strength-based and technically complex sports. Massage-induced changes in blood circulation indirectly influence metabolic processes by enhancing the transport of energy substrates and metabolic by-products between muscle tissue and the systemic circulation. Within the structure of training and competitive loads, this effect is especially important under conditions of short recovery intervals, when incomplete stabilization of the intramuscular environment leads to the persistence of metabolic stress and a reduction in strength characteristics [8, p. 1660].

In such cases, deep tissue massage functions as a passive regulator of recovery without imposing additional stress on the body's energy systems. The neuromuscular component of deep tissue massage is realized through the modulation of proprioceptive afferentation and the reduction of excessive motor unit activity in overloaded muscles. This process contributes to the normalization of muscle tone, improvement of intermuscular coordination, and restoration of motor program accuracy. In athletic training practice, these effects are important for maintaining technical stability of movements following intense or asymmetrical loads, particularly in sports that place high demands on precision and speed of motor control [2].

Thus, deep tissue massage in contemporary sports and rehabilitation practice serves not only as a means of reducing subjective manifestations of fatigue, but also as a tool for targeted influence on blood circulation, metabolic processes, and neuromuscular regulation. Its application enables controlled modulation of specific components of the recovery process, preserving the adaptive potential of training and reducing the risk of functional disorders.

An experimental assessment of the effects of deep tissue massage was conducted as a controlled comparative study of post-exercise recovery under fixed conditions with repeated measurements in the same group of participants. The aim of the experiment was to quantitatively determine whether the application of deep tissue massage alters the dynamics of blood lactate concentration and the rate of muscle strength recovery in the early post-exercise period compared with passive rest. The study employed a crossover design with two recovery sessions separated by an interval of 5–7 days, ensuring complete functional recovery and elimination of carryover effects. Participants were physically active individuals without acute injuries or contraindications to massage. All procedures were performed at the same time of day, with standardized diet and hydration, and with no intense training for 48 hours prior to each session. An identical warm-up protocol was completed before exercise.

A reproducible high-intensity interval protocol was used as the loading stimulus, designed to induce pronounced post-exercise stress without increasing the risk of injury. Immediately after completion of the load, one condition involved deep tissue massage of the target muscle groups for 10–12 minutes with controlled mechanical intensity, while the other condition involved passive rest under comparable temporal and postural conditions. Lactate concentration in capillary blood was measured using a validated portable analyzer, and muscle strength was assessed as maximal voluntary isometric contraction at a standardized joint position and angle using dynamometry. Measurements were obtained before exercise, immediately after exercise, and during recovery at fixed time points. Evaluators were blinded to the recovery condition.

Table 3

Dynamics of blood lactate concentration and muscle strength recovery after exercise under different recovery conditions

Time after exercise	Lactate, mmol/L <sup>-1</sup> (passive rest)	Lactate, mmol·L <sup>-1</sup> (deep massage)	Muscle strength, % of baseline (passive rest)	Muscle strength, % of baseline (deep massage)
Immediately after	9.8 ± 0.6	9.7 ± 0.5	72 ± 5	71 ± 6
5 min	8.6 ± 0.7	7.9 ± 0.6	78 ± 6	82 ± 5
10 min	7.4 ± 0.6	6.2 ± 0.5	82 ± 5	88 ± 4
20 min	6.1 ± 0.5	4.8 ± 0.4	86 ± 4	92 ± 3
30 min	5.2 ± 0.4	3.9 ± 0.3	90 ± 3	96 ± 3

*Source: author's own work*

Interpretation of the data revealed differences between recovery conditions, reflected in the characteristics of lactate-time and force-time curves. Under both conditions, peak lactate values and the initial decline in strength indicators immediately after exercise were comparable, confirming the equivalence of the exercise stimulus. During subsequent recovery, the application of deep tissue massage was associated with a more rapid reduction in lactate concentration, with pronounced differences evident as early as 10–20 minutes, as well as with higher levels of recovered muscle strength within the same time intervals. In practical terms, these findings indicate a shortening of the duration of functional limitations following intense work and an increased readiness to repeat strength or speed-strength actions within a single training session or between competitive episodes. Taken together, the results indicate that deep tissue massage applied in the early post-exercise period is associated with more favorable

metabolic recovery dynamics and a faster restoration of strength capabilities compared with passive rest. The observed effect has practical relevance for sports characterized by short recovery intervals and dense competition schedules, in which rapid functional recovery without additional physiological stress is critical.

The application of deep tissue massage in rehabilitation programs is accompanied by several scientific and practical challenges that limit the clarity of its effects and complicate the standardization of the technique. One of the key issues is the high interindividual variability in physiological responses to mechanical stress, resulting from differences in the morphofunctional state of the musculoskeletal system, fitness level, degree of fatigue, and prior exercise experience. When identical massage parameters are applied, some individuals may demonstrate accelerated recovery, whereas others may experience prolonged muscle stiffness or a transient reduction in strength, which complicates the prediction of outcomes [6, p. 191].

The dosage of mechanical impact remains a significant concern, as the intensity, duration, and localization of deep tissue massage are often determined subjectively and depend on the practitioner's experience and the patient's perceived sensations. Insufficient stimulus may fail to elicit a meaningful restorative effect, whereas excessive pressure can exacerbate tissue microtrauma, provoke protective neuromuscular responses, and delay the restoration of functional capacity [2]. The absence of objective criteria for regulating massage intensity further complicates its integration into scientifically grounded recovery protocols.

Methodological limitations are also associated with the timing of deep tissue massage in relation to physical activity. The optimal interval between the completion of exercise and the initiation of massage remains unclear, while premature intervention or application during incomplete acute recovery processes may alter the nature of adaptive responses. An additional challenge is the complexity of combining deep tissue massage with other recovery methods, as the cumulative effects of different interventions are not always additive and may result in mutual attenuation or amplification of undesirable reactions.

Scientific and practical difficulties are further related to the limited comparability of research findings, which arises from variability in massage techniques, differences in the selection of target muscle groups, measurement time points, and outcome indicators. This variability complicates data generalization and the development of unified recommendations for different types of sports activities.

The formulation of practical recommendations for the use of deep tissue massage in physical therapy and sports recovery should be based on the principle of aligning the restorative effect with the nature, intensity, and temporal structure of physical activity. Deep tissue massage should be applied primarily after high or submaximal intensity loads accompanied by significant localized muscle tension and a temporary reduction in strength indicators, as under these conditions its effects most effectively contribute to the optimization of recovery processes without imposing additional functional stress on the body.

Within the sports recovery system, massage should be integrated into the early or middle post-exercise period, when the primary acute responses to physical exertion have stabilized but functional tension within musculo-fascial structures persists. Under conditions involving multiple training sessions or competitive starts within a limited time frame, deep tissue massage should be applied selectively, with emphasis on muscle groups exposed to the greatest mechanical and neuromuscular stress, while avoiding total body massage that may produce an excessive systemic effect.

The intensity and duration of deep tissue massage should be adjusted according to the athlete's training level and functional condition. For highly trained individuals, moderately intense mechanical intervention of short duration is appropriate and should be directed toward restoring tissue mobility and reducing localized hypertonicity [9]. In physical therapy, particularly during recovery from overload or functional disorders, the use of gentler

modalities with a gradual increase in depth of impact is recommended, as this approach helps to avoid excessive reactions and supports positive recovery dynamics.

An important practical consideration is the integration of deep tissue massage with other recovery methods. It should be regarded not as a universal intervention but as a component of a comprehensive program that complements active recovery, corrective exercises, and load regulation strategies. At the same time, excessive accumulation of recovery interventions within a single hour should be avoided, as this may reduce the adaptive potential of the training process.

Overall, practical recommendations for the application of deep tissue massage should be based on an individualized approach, regular monitoring of functional status, and clear coordination of massage procedures with the structure of the training or rehabilitation process. This approach ensures a restorative effect without disrupting long-term adaptations and enhances the effectiveness of physical therapy and sports recovery under conditions of varying physical activity intensity.

### Conclusions

The study found that deep tissue massage applied in the early post-exercise period is associated with accelerated kinetics of blood lactate concentration reduction and faster muscle strength recovery compared with passive rest. The data obtained indicate that the effect of massage is not only subjective but is accompanied by objective changes in metabolic and functional indicators that are critical for readiness for repeated physical exertion within a single training or competition cycle.

At the same time, several scientific and practical challenges have been identified in the application of deep tissue massage, including high individual variability in physiological responses, the lack of standardized parameters for dosing mechanical stimulation, and methodological heterogeneity of procedures. These factors complicate the prediction of outcomes and limit the potential for unifying recovery protocols in sport and physical therapy.

Based on the results obtained, the feasibility of individualized use of deep tissue massage as part of comprehensive rehabilitation programs, taking into account load intensity and functional status, is substantiated. Prospects for further research are related to clarifying the dose-dependent effects of massage, developing objective criteria for controlling mechanical stimulation intensity, and assessing its long-term effects on adaptive processes and the stability of muscular performance.

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