



Original Article

Effects of friction massage of the popliteal fossa on dynamic changes in muscle oxygenation and ankle flexibility

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Abstract. [Purpose] This study aimed to examine whether or not friction massage of the popliteal fossa would be effective for achieving dynamic changes in muscle oxygenation and ankle flexibility. [Subjects and Methods] Twelve healthy male university students participated. Before and after friction massage, dynamic changes in muscle oxygenation and ankle flexibility were measured by near-infrared spectroscopy to evaluate its efficacy. [Results] Oxygenated hemoglobin was significantly higher after as compared to before massage. The range of ankle dorsiflexion tended to increase after massage. [Conclusion] These results suggest that friction massage of the popliteal fossa stimulates venous return in the lower leg.

Key words: Friction massage, Muscle oxygenation, Near-infrared spectroscopy

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INTRODUCTION

Massage therapy has been defined as manipulation of soft tissue by a therapist trained in performing this treatment¹⁾. Massage therapy is applicable locally or to the whole body. Its effects include improved blood flow, reduction of muscular tension, improved autonomic nervous function, and improvements in the flexibility and range of motion (ROM) of joints²⁾. This therapy is often used for purposes such as conditioning, prevention of injury, and alleviation of pain. The efficacy of massage has recently begun to be reported based on scientific evidence²⁻⁴⁾. At present, international treatment guidelines include massage as one of the recommended therapeutic methods^{5, 6)}, and scientific evaluations of massage therapy have been carried out.

Various diverse physiological mechanisms have been said to underlie the effects of massage. Among the noted effects, the stimulation of muscle, fascia, and other tissues has been said to: improve blood and lymph circulation; diminish excitation, pain, etc. of dysfunctioning muscles and nerves; improve regulation of the functions of nerves, muscles and internal organs; increased elasticity of shortened tissues through correction of adhesions; and so on^{7, 8)}. On the basis of this view, reports have been published concerning the effects of massage on flexibility, blood flow and psychological/physiological features⁹⁻¹¹⁾, as well as on the involvement of massage in recovery of performance, blood lactic acid levels, delayed onset muscle soreness and so on¹²⁻¹⁴⁾. As seen in the above-cited previous studies, massage therapy mostly targets muscles for the purpose of adjusting musculoskeletal conditions¹⁵⁾, and many of the published studies pertained to approaches involving muscles.

Friction massage, which we have employed, is one of the basic massage techniques. It is often used for joints and sur-

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rounding soft tissues other than muscles. To our knowledge, however, there have been few reports concerning the physiological effects of massage on sites other than muscles. Friction massage consists of motions on local areas, applied gradually and deeply, and is known to have the effect of stimulating circulation through the joints and alleviating contractures. Patients who have experienced an Achilles tendon tear and athletes sometimes show intense hypersensitivity and swelling of the medial and lateral heads of the gastrocnemius muscle surrounding the popliteal fossa as well as lower leg edema and so on. Furthermore, patients with osteoarthritis of the knee and similar conditions have also been reported to show hardening of the medial and lateral heads of the gastrocnemius muscle (corresponding to the area supplied by the popliteal vein) and intermediate sites, leading to the complaint of hypersensitivity¹⁶). Friction massage of such an area in the vicinity of the popliteal vein can reduce tenderness. The authors thus hypothesized that these symptoms are related to retention of venous blood specific to the lower leg.

Near-infrared spectroscopy (NIRS) is a tool allowing noninvasive evaluation of the oxidized and reduced state of tissue oxygen. This study was designed to apply friction massage to the area supplied by the popliteal vein for the purpose of analyzing relative changes in hemoglobin levels and blood volumes within the triceps surae muscle by means of NIRS and evaluating the influence on the ankle's ROM.

SUBJECTS AND METHODS

During this study, friction massage was performed on the area supplied by the popliteal vein in healthy volunteers. Changes in deoxygenation within the triceps surae muscle and ankle ROM were monitored before and after intervention (a comparative study: after versus before).

In accordance with the principles of the Declaration of Helsinki, this study was designed with adequate care to prevent physical/mental stress and the privacy of our subjects was protected. Subjects were recruited at the Ibaraki Prefectural University of Health Sciences. Twelve men having signed the consent form, satisfying the eligibility criteria and signing the consent form after receiving an explanation of the study's objectives, methods, benefits/risks, subject's rights and so on were enrolled. Mean body height was 174.6 ± 3.2 cm; body weight, 59 ± 2.28 kg; and body mass index, 19.4 ± 0.6 .

The study protocol was approved in advance by our institutional review board. The inclusion criteria were: healthy men 20–29 years of age, free of neurological abnormalities at the time of the experiment, no history of orthopedic disease or surgery on the extremities and/or trunk within one year prior to the study, absence of physical training as an exercise club member within 1 month prior to the study, free of pain at the time of the experiment, and able to complete the experiment.

Parameters measured with NIRS (NIRO-300, Hamamatsu Photonics Co., Ltd. Japan) were oxygenated hemoglobin (oxy-Hb), deoxygenated hemoglobin (deoxy-Hb) and total hemoglobin (Total-Hb) levels. The probe was placed on the medial and lateral heads of the right gastrocnemius muscle, with the subject in the prone position. Friction massage was performed on the point intermediate between the medial and lateral heads of the gastrocnemius muscle. Friction massage was performed with thumbs, moving them in small circles ($2\text{--}3\text{ cm}^2$) at a frequency of 3 Hz.

According to the experiment protocol, a 15-minute acclimation period was followed by HB level measurement with NIRS for 10 minutes before the test friction massage. Then, friction massage was applied for 2 minutes, followed by a 20-minute HB level measurement (Fig. 1). The experiment was carried out in air-conditioned environments with the temperature set at $24\text{--}26^\circ\text{C}$ and relative humidity at 40–60%. All subjects experienced the aforementioned 15-minute acclimation period for the purpose of adjustment to these environmental conditions.

Statistical analyses focused on differences between pre-friction and post-friction values (Δ) in hemoglobin concentrations (oxy-Hb, deoxy-Hb, Total-Hb) measured with NIRS. Ankle ROM on the massaged side was passively measured during knee extension in the prone position, using a goniometer (P.O Box555, Smith & Nephew, Rolyan Inc.). Changes in parameters were compared using within-subject paired t-tests. All statistical tests were performed using IBM SPSS statistics version 21.

RESULTS

Oxy-Hb or total-Hb after differed significantly from that before friction (Table 1). The level of oxy-Hb before 2-minute friction began to rise immediately after the start of its application, reaching a level 7 times the pre-friction level at 20 minutes after its initiation. There was no significant difference in deoxy-Hb between the pre-friction and post-friction measurements (Table 1). The ROM of ankle dorsiflexion was larger after friction, although the difference was not statistically significant. The ROM of ankle plantar flexion was unchanged (Table 2).

DISCUSSION

In this study, we investigated the effects of friction massage on dynamic changes in muscle oxygenation and evaluated the influence of this intervention on ankle flexibility.

Analyses of Δ oxy-Hb ($\mu\text{mol/l}$) and oxy-Hb levels after friction revealed values to be significantly higher than before friction. This result suggests that friction massage on the area supplied by the popliteal vein affects muscular oxygenation. The lower leg area, including the gastrocnemius muscle has a specific vascular form, and the muscular oxygenation in this

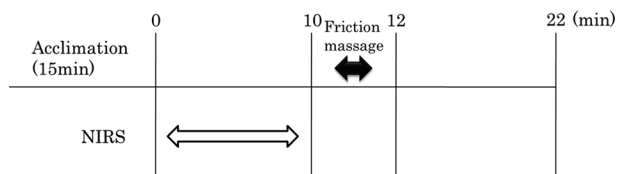


Fig. 1. Experimental protocol

The near-infrared spectroscopy (NIRS) measured changes in hemoglobin during a 10-minute rest set before the test friction massage. Friction massage was applied for 2 minutes, followed by a 20-minute HB level measurement.

Table 2. Changes in the ROM of ankle joint (°)

Motion	Pre	Post
*Dorsiflexion	18.4 ± 2.3	22.8 ± 1.5
Plantar flexion	43.8 ± 3.1	43.3 ± 3.1

Values are expressed as means ± SD. *p<0.01

Table 1. Dynamic changes in muscle oxygenation (μmol/l)

ID no.	ΔOxy-Hb	ΔDeoxy-Hb	ΔTotal-Hb
1	6.7	-3.8	0.8
2	3.1	1.8	0.6
3	4.8	-0.3	0.3
4	5.8	1.3	0.2
5	7.3	-1.4	0.4
6	7.7	-0.9	0.5
7	7.2	-3.4	1.6
8	10.5	3	0.6
9	5	-1	0.2
10	6.2	-2.2	0.1
11	3.9	0.1	1.2
12	3.1	-3.2	0.2
	5.9 ± 2.1*	-0.8 ± 2.1	-0.6 ± 0.45*

Values are expressed as means ± SD. *p<0.01

area can be adversely affected by lower leg compartment syndrome, deep vein thrombosis, edema, venous stasis, and so on.

The oxy-Hb, measured in this study, is Hb bound to the oxygen dissolved from alveoli into plasma, and its rise probably reflects an increased arterial blood volume in the local portion of the lower leg. There was no sharp change in deoxy-Hb or total-Hb, suggesting that oxy-Hb increased relative to deoxy-Hb (not bound to oxygen), resulting in a relative increase in arterial blood volume. The mechanisms underlying the changes in muscular tissue oxygenation seen in this study appear to involve friction-induced stimulation of the area in the vicinity of the popliteal vein (a site anatomically characterized by the confluence of returning venous blood flow¹⁷) and actions exerted on the autonomic nervous system¹⁸). It is likely that alleviation of blood stasis and stimulation of muscular metabolism resulted in increased flexibility of the gastrocnemius muscle and increased ankle ROM.

Metabolic diseases (e.g., diabetes mellitus) and disturbed blood circulation are clinically known to stimulate the release of substances responsible for muscular fatigue and pain, which then cause further pain, muscular spasm, reduction of articular flexibility and so on^{19, 20}). Therefore, activation of muscular oxygenation is clinically important. It is, in addition, expected to facilitate repair of injured tissues, recovery from fatigue and so on in postoperative patients and athletes.

Our results can serve as scientific evidence for the therapeutic efficacy of friction massage, a subject on which few studies have been conducted to date. However, there are still many open questions regarding the mechanisms underlying the effects of friction massage observed in this study. It is desirable to continue this type of study, by also focusing on the autonomic nervous system, blood flow velocity, vasodilation measurements and other relevant factors.

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