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Effect of massage on blood flow and muscle fatigue following isometric lumbar exercise

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: This study attempted to investigate the influence of massage on the skin and the intramuscular circulatory changes associated with localized muscle fatigue.

Material/Methods: Twenty-nine healthy male subjects participated in two experimental sessions (massage and rest conditions). Subjects lay prone on the table and were instructed to extend their trunks until the inferior portion of their rib cage no longer rested on the table. Subjects held this position for 90 seconds (Load I). Subjects then either received massage on the lumbar region or rested for 5 minutes, then repeated the same load (Load II). Skin blood flow (SBF), muscle blood volume (MBV), skin temperature (ST), and subjects' subjective feelings of fatigue were evaluated using Visual Analogue Scale (VAS).

Results: An increase of MBV between pre- and post-load II periods was higher after massage than after rest ($p<0.05$). An increase of SBF at pre- and post-load II was observed only under massage condition. An increase of SBF between post-load I and pre-load II periods was higher after massage than after rest ($p<0.05$). An increase of ST between post-load I and post-load II periods was greater after massage than after rest ($p<0.05$). The VAS score was lower with massage than with rest in the post-treatment period ($p<0.01$).

Conclusions: A significant difference was observed between massage and rest condition on VAS for muscle fatigue. Lumbar massage administration also appeared to have some effect on increasing skin temperature and enhancement of blood flow in local regions.

key words: massage • muscles • blood flow • near infrared spectroscopy • skin temperature • muscle fatigue

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BACKGROUND

Localized muscle fatigue is defined as the fatigue that is localized in the muscle or group of synergistic muscles performing contraction [1]. Localized muscle fatigue can be induced by sustained muscular contractions and is associated with such external manifestations as the inability to maintain a desired force output, muscle tremor, and localized pain [2]. One cause of fatigue is restriction of blood flow to actively contracting muscles [3]. Insufficient delivery of oxygen and inadequate removal of metabolic waste products can occur without adequate blood flow to muscles [4].

In clinical and sports settings, massage is utilized widely and believed to be efficacious in the recovery from muscle fatigue [5,6]. Massage is thought to increase tissue circulation, thereby decreasing hypertonicity and enhancing recovery from muscle fatigue [7]. Although a number of attempts have been made to investigate the effects of massage on the circulatory system, the outcomes have been contradictory, as indicated in previous literature reviews [8–10].

Most of these studies have recorded only the blood flow to the skin [11], the gross blood flow volume in surrounding tissues [12], or else indirect measures were used, such as skin temperature [13–15]. If increased blood flow only occurs in the skin, then there is little for muscle tissue to gain from it [16].

Drust et al [17] demonstrated that there was a greater increase of skin and intramuscular temperature (at 1.5 and 2.5 cm depth) following massage than following ultrasound, however, no significant differences between massage and ultrasound were noted when deeper intramuscular temperature was measured at 3.5 cm depth. The technique that was used to measure intramuscular temperature involves insertion of a needle thermistor into the muscle.

Only a few studies can be found in which the effect of massage on intra-muscular circulation was measured and evaluated. Hovind and Nielsen [18] studied the effect of massage on blood flow in skeletal muscle using the local washout technique with ^{133}Xenon as a tracer. There was an indication of possible blood flow increase after a tapotement (hacking) technique was administered but a petrissage (kneading) technique showed little effect. Hansen and Kristensen [19] concluded, based on their experiment using a ^{133}Xenon clearance technique, that massage has little effect on muscle and subcutaneous circulation in the human calf.

The method used to measure the intra-muscular blood flow in Hovind and Hansen's experiments [18,19] was an invasive procedure requiring an injection of the radioactive isotope ^{133}Xenon in order to measure the blood flow. Local hyperemia is well-known to be induced by this procedure [20]. In addition, systemic physiological reactions may have occurred following this procedure due to the stimulation caused by its invasive nature. These reactions make it difficult to evaluate any physiological changes directly related to the massage stimulation.

This study measured skin and intramuscular blood flow non-invasively using near infrared spectroscopy (NIRS) and infrared thermography. The advantage of using NIRS to assess intramuscular blood flow is that it is non-invasive and it can be performed repeatedly without discomfort or risk to the subjects [21]. In addition, subjects' back muscle fatigue was evaluated on a visual analog scale (VAS) by the subjects. This study attempted to investigate the influence of massage on the skin and intramuscular circulatory change associated with localized muscle fatigue.

MATERIAL AND METHODS

Subjects

The subjects recruited were students at the Tsukuba College of Technology in Ibaragi, Japan. Subjects were recruited for this experiment according to the following criteria; no present low back pain or episodes of serious low back pain in the last five years, no reported abnormal spinal X-ray findings, and no history of major physical or mental illness.

Thirty male subjects initially enrolled in this study. However, one subject dropped out from the study due to being unable to sustain a required task load. Twenty-nine subjects (age 22.4±4.2 years; height 169.3±4.8 cm; body mass 64.9±8.1 kg; BMI 22.8±2.7) completed the study. Each subject was fully informed of the experimental procedures and signed an informed consent statement before taking part in the study.

Procedure

Each of the 29 men participated in two experimental sessions conducted on separate days. The interval between each session was greater than one week in order to avoid carry-over effects. Fifteen subjects received massage in the first experimental session and rest in the second session, while the remaining 14 subjects received intervention (massage or rest) in reverse order.

Before each session, subjects were asked to lie in a prone position on a treatment table with their hands crossed behind their heads. After the proper attachment of electrodes was confirmed, subjects were instructed to slowly extend their trunks until the inferior portion of their rib cage no longer rested on the table. Subjects then held this position for 90 seconds before slowly returning to the resting position (Load I). They then received either massage on the lumbar region or rested for 5 minutes (see Table 1 for description of the intervention). Subjects were then asked to extend their back in the same manner as before (Load II). The experimental procedure is summarized in Figure 1.

Measurements

Muscle blood volume (MBV) and skin blood flow (SBF) were measured using a laser blood flow meter (ALF21D,

Table 1. Description of the Intervention.

	Intervention
Rest	The subject rested on the treatment table in the prone position for 5 minutes
Massage	Effleurage, kneading and compression techniques were applied to the lumbar and sacrum region for 5 minutes. The massage treatment was provided by a licensed therapist in Japan

Advance Co, Ltd.) and near infrared spectroscopy (PSA-III N, Biomedical Science Co, Ltd.). The measurement probes were placed on the right lumbar paraspinal muscles. The SBF and MBV were recorded before and after the Loads for a duration of 60 seconds. Subjects' skin temperatures (ST) were also monitored continuously during the experiment using thermography (JTG-3300, Japan Electron Optics Laboratory Co, Ltd.). Thermographic data of the right lumbar region before and after Loads was used for later analysis. Moreover, subjects' subjective feelings of fatigue were evaluated using a VAS [22]. Immediately after each load, subjects were asked to evaluate their level of fatigue on the VAS which is 100 mm long vertically. The left end of the scale (at 0 mm.) is indicated as 'no fatigue' and the right end of the scale (at 100 mm.) is indicated as extreme fatigue.

Statistical analysis

Muscle and skin blood flow was analyzed using a multivariate (muscle/skin), doubly-repeated measures ANOVA for Intervention type (massage/rest) and Time (pre-load I, post-load I, pre-load II, post-load II). The statistical results do not differ when the pre-load I measurements are used as covariates. The order of administration of the treatments was not found to be related to any significant effects, and therefore we omitted it from our analysis. The temperature was analyzed using a doubly-repeated-measures 3×2 ANOVA for the repeated factors: the times at which the measurements were taken (pre-load I, post-load I, post-load II), and type of treatment received (massage/rest). The order in which the interventions were administered (treated by massage first/treated by rest first) was included in the design but it was excluded from the analysis after we found that it did not have any statistically significant effect. The visual analogue scale was analyzed using a doubly-repeated-measures 2×2×2 ANOVA for the repeated factors: the times at which the measurements were taken (post-load I, post-load II) and type of intervention received (massage/rest). The repeated measures design was then crossed with the factors between the subjects: the order in which the treatments were administered (treated by massage first/treated by rest first). A p-value less than 0.05 was considered to be of statistical significance.

Results

Muscle and skin blood flow

In the muscle blood volume there was evidence of a change over time, $F(3, 84)=3.70$, $p<0.05$. An increase of MBV at post-load II period was observed under massage condition ($p<0.01$, Table 2). *Post hoc* analysis further indicated that an increase of MBV between pre- and post-load II periods was higher after massage than after rest (Table 3). In the case of skin blood flow there was evidence that the changes over time differ between massage and rest, $F(3, 84)=3.70$, $p<0.05$. An increase of SBF at pre- and post-load II was observed only under massage condition (Table 2). An increase of SBF between post-load I and pre-load II periods was higher after massage than after rest ($p<0.05$, Table 3).

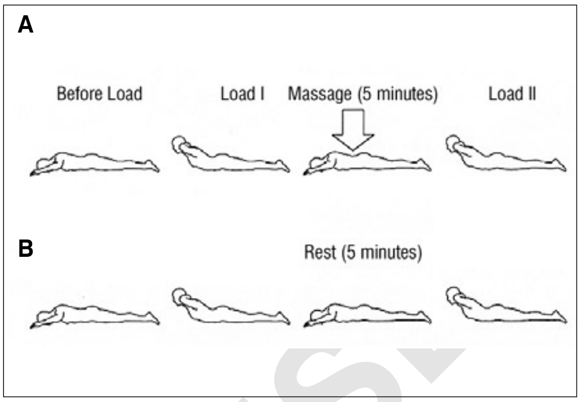

Figure 1. Experimental Procedures. (**A**) Subjects received massage (Massage condition). (**B**) Subjects rested (Rest condition).In both Load I and II, subjects were in a prone position with their hands crossed behind their heads and then subjects were instructed to slowly extend their trunks until the inferior portion of their rib cage no longer rested on the table. Subjects then held this position for 90 seconds before slowly returning to the resting position. Physiological measurements were conducted before and after Load I and after Load II.

Skin temperature

There was an interaction between the type of treatment and the times at which the measurements were taken, $F(2, 56)=8.24$, $p<0.01$. At all measurement times the mean temperature under massage condition (M=34.65, SD=0.68, N=29) was higher than under rest (M=33.76, SD=0.54, N=29), $t(28)=8.13$, $p<0.0005$. The skin temperature at each measurement period is summarized in Table 4. An increase of ST between post-load I and post-load II periods was greater after massage than after rest ($p<0.05$, Table 3).

Visual analog scale

There was an interaction between the times at which the measurements were taken and the type of treatment received, $F(1, 27)=12.06$, $p<0.01$. There is not sufficient statistical evidence to conclude that the pre-treatment VAS measurement differed between massage and rest ($t(27)=1.17$, ns.). In the post-treatment period, VAS was lower with massage (M=42.92, SD=20.30, N=29) than with rest (M=59.01, SD=20.82, N=29), $t(27)=3.53$, $p<0.01$. The VAS at post-load I and II measurements is shown in Figure 2.

Table 2. Muscle Blood Volume and Skin Blood Flow at each measurement period under massage and rest condition.

		Pre-load I	Post-load I	Pre-load II	Post-load II
Massage	MBV (mv)	271.67±133.8	273.09±128.11	277.08±130.67	291.09±135.29**
	SBF (mv)	34.13±15.63	40.01±26.42	42.29±26.07*	43.32±12.8**
Rest	MBV (mv)	265.47±117.52	264.51±109.61	271.35±112.53	274.07±115.83
	SBF (mv)	24.84±8.94	26.95±8.4	21.23±5.92	26.44±11.63

Data presented are mean ±SD
* $p<0.05$ vs baseline;
** $p<0.01$ vs baseline

Table 3. Muscle Blood Volume, Skin Blood Flow, and Skin Temperature changes between measurement periods under massage and rest condition.

	Rest	Massage
MBV (mv)		
Pre-load I – Post-load I	–0.96±22.89	1.42±17.27
Post-load I – Pre-load II	6.84±12.16	3.99±27.83
Pre-load II – Post-load II	2.72±11.77	14±16.79*
SBF (mv)		
Pre-load I – Post-load I	2.11±9.42	6.67±14.03
Post-load I – Pre-load II	-5.72±6.70	1.68±12.32*
Pre-load II – Post-load II	5.21±9.30	1.03±20.09
ST (°C)		
Pre-load I – Post-load I	–0.2±0.24	–0.2±0.4
Post-load I – Post-load II	0.09±0.25	0.45±0.48*

Data presented are mean ±SD
* $p<0.05$ vs rest

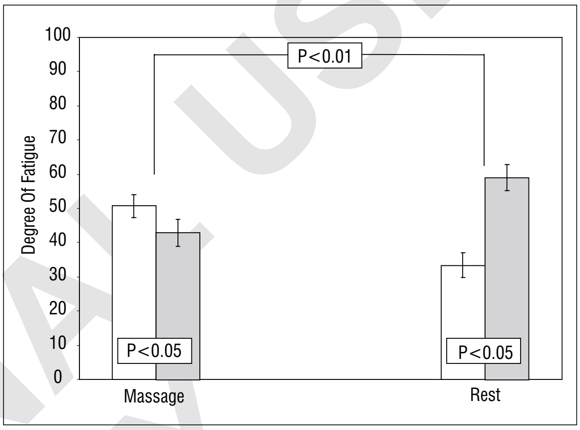

Figure 2. Changes in Feelings of Fatigue on VAS. The bar graph shows changes of fatigue rating measured on 100 mm VAS scale after load I and II. Significant decrease of VAS score is shown when massage was administered while increase is indicated under rest condition. Data presented are mean ±SE.

Table 4. Skin Temperature (°C) at each measurement period under massage and rest condition.

	Pre-load I	Post-load I	Post-load II
Massage	34.64±0.71	34.43±0.79	34.88±0.71
Rest	33.87±0.55	33.67±0.53	33.76±0.60

Data presented are mean ±SD

Discussion

Increases in blood and lymph flow are the most frequently described physiological effects of massage therapy [9]. This investigation evaluated the possible circulatory effects of massage by measuring MBV, SBF, and ST.

Influence of massage on MBV is particularly important since the effect is thought to help enhance removal of metabolic waste by-products such as lactic acid, thus enhancing recovery from muscle fatigue [8]. Tiidus and Shoemaker tested the efficacy of massage on circulation using the laser Doppler flow meter. The study showed that simple repetitive knee flexion and extension was more effective in increasing calf circulation than massage [23]. The present study showed significant muscle blood volume increase after Load II, which was observed only under massage condition. In addition, the MBV increase between the pre- and post-load II measurements was significantly higher in massage condition than rest. Since this study used rest as a form of control condition, it cannot be determined whether or not massage application is useful for increasing MBV compared to dynamic warm-up exercise such as repetitive trunk rotation.

On VAS, subjects' feelings of local muscle fatigue significantly decreased after Load II when subjects received massage, while feelings of fatigue significantly increased after Load II when subjects rested. This study did not employ any objective markers to assess muscle fatigue. However, we have conducted a separate study using the same load type and massage duration which used frequency analysis of electromyographic (EMG) signals to objectively assess fatigue [24]. The frequency analysis of the EMG signals in particular has been recognized as a useful tool for the measurement of local muscle fatigue [25,26]. The lower EMG power spectrum shift during fatigue is considered to be related to biochemical by-product accumulation (H^+ and lactic acid) in the muscle, which changes the action potential conduction velocity [27]. If massage application helps increase local circulation and decrease metabolic waste products, it is reasonable to expect changes in the EMG power spectrum (i.e, decreased mean and median frequency slope decline during the 90-second contraction). However, in our study [24] a significant change in EMG parameters was attributed to the time effect. The ANOVA indicated some evidence that the Intervention (massage or rest) may have influenced the change in mean frequency (MNF), although, the *post hoc* analysis could not reveal any further details, possibly due to the minute difference in MNF changes. The present study showed significant muscle blood volume increase after Load II, which was observed only under massage condition. However, the difference between massage and control (rest) condition is not very large in terms of overall increase of MBV (from baseline to post II measurement). The increase of MBV under massage application was only 7%, while control condition also showed an increase of MBV (3%), presumably from isometric exercise effect. The small degree of change in muscle blood flow might be one of the reasons why we could not observe a significant effect on EMG indices in our previous study.

There have been previous studies which attempted to investigate the efficacy of massage by examining the blood lactate concentration [28–30]. Their results showed that there are no significant effects of massage in enhancing lactate removal compared to rest or low intensity exercise. These studies however tested the effect of massage on lactate concentration by evaluating blood samples collected from the subjects' fingertips while massage and fatigue inducing load were administered to other muscle groups. Therefore, those studies were evaluating the systemic influence of massage, whereas the present study was designed to elucidate the localized effect of massage application.

This study also showed an increase of skin blood flow after massage. In addition, a skin temperature increase between post-load I and II was significantly greater with massage than rest. However, the degree of skin temperature change seems small (0.45°C increase from post-load I to post-load II) compared to those previously published which showed an increase of 2–3°C in thigh skin temperature after massage relative to therapeutic ultrasound application [17]. Furthermore, it is not clear as to whether the increase was due to massage, heat conduction from the therapist's hands, or both. This is one of the limitations of the present study protocol. A future study should be conducted having the therapist's hands statically placed on the subject's back as the control condition. It should also be noted that the conclusions from our study are not applicable to massage treatments of longer duration, wider areas of application (i.e., full body massage), or where different techniques are employed. Furthermore, since localized fatigue was induced after 90 seconds of sustained contraction, the conclusions cannot be extrapolated to situations where fatigue was caused by activity of a different duration or intensity.

Conclusions

Massage application on the lumbar region provided a decrease in the fatigue scale as compared to rest suggesting that massage application helped the subjects overcome the subjective feeling of the fatigue. The increase of MBV, SBF, and ST observed after massage application suggests that a decrease of muscle fatigue may be associated with efficient removal of metabolic wastes by massage. An additional study using active control conditions and incorporating objective fatigue indices is necessary in order to further validate the clinical usefulness of massage treatment.

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