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THE EFFECTS OF THAI MASSAGE ON LEG MUSCLE OXYGENATION AND TIME TO FATIGUE IN HEALTHY MALE SUBJECTS

Wirapong Sucharit[1], Wichai Eungpinichpong[2], Uraiwan Chatchawan[3], and Punnee Peungsuwan[4]

[1]Back, Neck and Other Joint Pain Research Center (BNOJP), Thailand
[2,3,4]Faculty of Associated Medical Science, KhonKaen University, Thailand

*Corresponding Author, Received: 25 Nov. 2018, Revised: 27 Dec. 2018, Accepted: 21 Jan. 2019

ABSTRACT: Thai massage is a kind of alternative medicine commonly used in Thailand for relieving of muscle fatigue and pain. Several studies reported that it can increase blood circulation. This may be due to increasing muscle oxygenation and time to fatigue. However, there is no evidence to support. A cross-over study design was employed to evaluate the effects of Thai massage on leg muscle oxygenation, time to fatigue and muscle force. Twenty-six healthy males were allocated to receive isometric exercise by performing series of 10s of sustained contraction and 5s rest until they reach peripheral fatigue point where the quadriceps torque declined to less than 60% of peak torque in the last 10 times (control period). Conversely, they received a 60-minute session of Thai massage before isometric exercise (massage period). The results showed that after massage, the muscle oxygenation was significantly increased (79.47±9.24%) ($P < 0.05$) when comparing to control period (75.04±10.68%). In addition, the time to fatigue and quadriceps muscle force revealed no significant differences ($P > 0.05$) although the massage period tended to have more prolonged duration (8.74±2.68 min.) than the control period (7.82±1.79min), and massage period showed higher quadriceps muscle force. As a result, Thai massage is effective to increase muscle oxygenation levels. Also, it seems to be associated with increased duration of isometric muscle fatigue and higher muscle force.

Keywords: Thai massage, muscle oxygenation, time to fatigue, isometric exercise.

INTRODUCTION

Basic characteristic of Traditional Thai Massage (TTM or Nuad Thai) includes deep pressure massage along the meridian lines (SenSib) of the body using sustained pressure by thumbs, palms or elbows of a practitioner, and muscle stretching technique. Moreover, TTM is also used in many athletes or patients for increasing muscle blood circulation and time to fatigue; however, there is not any evidence to support these methods [1]. Several studies report that TTM can increase skin blood flow, skin temperature, and muscle blood volume, but the study has used Laser Doppler technique where the depth of measurement may not reach the muscle layer, so stimulation of muscle blood flow has not been verified [2].

Recently, near-infrared spectroscopy (NIRS) was developed to measure clinical muscle with 17.5mm. depth length of measurement. NIRS is a non-invasive technique and multiple-wavelength method based on the principle of Beer-Lambert law used for continuous measurement of muscle blood flow including intravascular hemoglobin (Hb), intra muscular myoglobin (Mb), muscle oxygenation, and tissue oxygen index [3]-[5]. Currently, NIRS has high reproducibility and agreement with gold standard techniques [6]. Previous studies show that NIRS can be used to study both athlete and clinical assessment [7]-[10].

The sustain isometric muscles contraction increasing intramuscular pressure (IMP) linearly and ultimately reaches a critical level which compresses intramuscular blood vessel resulting in impaired circulation [11], alterations in O_2 delivery, and other substrate. These affect working muscles and lead to lower muscle oxygen saturation throughout exercise [12], which causes increased acidity of blood and muscle cells [13], [14]. Additionally, the study of Hepple [15] on localized muscle fatigue reports that hypoxia or ischemia condition of exercise is related to muscle force decreased. Therefore, oxygen is an important factor contributing to muscle fatigue [16]-[18]. However, the study of Murthy [19] determining the relationship between muscle oxygenation and twitch force demonstrates positive correlation (r = 0.78). Also, this study shows that ischemia and muscle hypoxemia is probably the cause of muscle fatigue. Conversely, TTM can increase local muscle microcirculation, lymph flow, and muscle flexibility but reduce muscle stiffness [1]. Thus, this study speculates that TTM may improve muscle oxygenation, time to localized muscle fatigue, and muscle force.

MATERIALS AND METHOD

Subjects

Male healthy subjects were recruited using oral requests and bulletin boards. They were screened by researcher and rechecked by internist using developed inclusion criteria; male between 18-35 years of age, no history of cardiopulmonary problems (i.e. heart arrhythmias, aortic stenosis, pulmonary embolus), no reported hypertension (i.e. uncontrolled hypertension with diastolic above 110 mmHg. and systolic above 180 mmHg.) [2], [20]-[21], no present acute pain in isometric exercise [21], and values of adipose tissue thickness (ATT) less than 6.7 mm [5]. Subjects must not recently receive caffeine, nicotine, alcohol, and mixed meal or a glucose load within 30 min well as perform any extensive physical activity[20].

Twenty-eight male subjects initially enrolled in this study. But, two subjects dropped out from the study due to loss of follow up in final session. Twenty-six subjects (22.62±2.43 years of age; height 173.2±6.6 cm; body mass 68.8±6.9 kg; BMI 22.9±2.0; ATT 3.9±1.2 mm) completed the study. Each subject was informed about the experimental procedures and signed an informed consent statement before taking part in the study. The study was approved by the Human Research Ethics Committee of KhonKaen University (Fig.1).

Procedures

Each of twenty-six male participated in two experimental sessions conducted on separate days. The interval between each session was one week [22] in order to avoid carrying over effects. The subjects who meet the inclusion criteria were randomly assigned to the first experimental session control group or TMM group based on a computer-generated block randomization code. Then they received intervention in reverse order [23].

Before getting into TTM or control group, the subjects were allowed to wear comfortable clothes and familiarized with the testing procedure by performing isometric muscle contraction for 5 times. Later, subjects who were randomized into TTM group were asked to lie in a supine position on a treatment table for one-hour Thai massage by an experienced therapist while control group lie in the same position only. Then both groups received fatiguing protocols using quadriceps broad connected with electronic scale. The subjects comfortably lied supine with the Rt. Knee joint flexion at 25º-30º on quadriceps broad while the opposite leg was placed in the appropriate posture, and arms were placed across the chest with each hand clasping the opposite shoulder during testing [24]-[28]. The subjects were asked to perform maximal isometric voluntary contraction (MIVC) i.e. 10s for sustain and 5s for rest until reaching the localized muscle fatigue; the point at which the last 10 contractions decreased less than 60 percentage of peak torque. The peak torque was defined as the highest torque obtained from the first 3 maximal isometric contractions at baseline [29] (Fig.2).

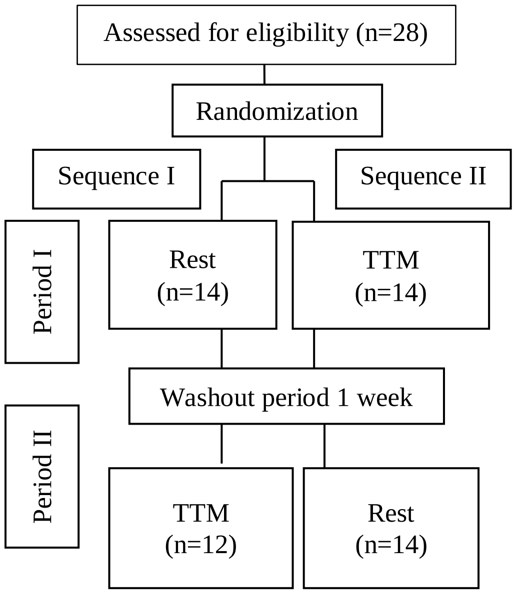

Fig. 1 Procedures of experimental study

Measurements

Muscle oxygenation was measured by NIRS (MOXY oxygen monitor; SROC: r = 0.842-0.993, ICC: r = 0.773-0.992) [30]. It is noninvasive technique which is able to continuously measure covering after received intervention, highest muscle force period, continuous MVIC to fatigue muscle force period, and recovery period to monitor the changes in muscle tissue saturation. The probe of NIRS was positioned on the belly of right vastus lateralis muscle (about 10 cm from the center of the patella and 25º laterals to the midline of the thigh) [31]. Pen-marks were made in transparent to confirm the margins of the probe to enable reproduction of the placement position in the subsequent procedure. The probe was secured with tape. Then black elastic bandages were wrapped around the leg with MOXY to protect artifacts.

Time to fatigue was recorded by video recording starting from the first MVIC to fatigue point.

The quadriceps muscle force was measured using a quadriceps broad [24] that Rt. distal leg at lateral malleolus was fixed with electronic scale (ICC=0.908) which passed calibrates. Then muscle torque and muscle force were calculated by equation of joint moment as Eq. 1, 2, and 3.

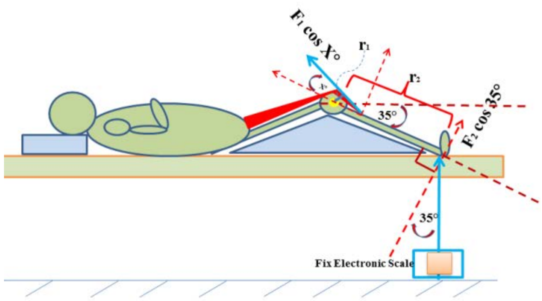

Fig. 2 Position of moment arms and joint angle

Equations

Muscle torque can be calculated based on magnitude of force multiplied by distance from the fulcrum dragged perpendicular to the force as the equations below [32]:

$$F_2 = ma$$
$$F_2 = (kg)\ (9.8m/s^2) \quad (1)$$

$$M_2 = F_2 \times r_2$$
$$M_2 = F_2 \cos 35^o \times r_2 \quad (2)$$

Quadriceps muscle force can be calculated on balance of joint moment.

$$\Sigma M = 0$$
$$M_1 + M_2 = 0$$
$$F_1 \cos X°(r_1) + (-)\ F_2 \cos 35°\ (r_2) = 0$$
$$F_1 = F_2 \cos 35°\ (r_2) / \cos X°(r_1) \quad (3)$$

(M =magnitude of moment or torque, F= magnitude of leg kick (kg), r=distance (m) from the fulcrum dragged perpendicular to the force)

Statistical Analysis

Subjects' baseline characteristics were presented as mean ± standard deviation (SD). Each variable was evaluated by Shapiro–Wilk test in terms of normal distribution. The carryover effects were measured sequence, period, and treatment effects using *cross analysis* methods [36] and sample *t*-tests. Comparisons for the dependent variables within groups were analyzed using repeated measures *ANOVA*. Paired sample *t*-tests analyses were used to compare the pairs of means between groups. Data were analyzed using the SPSS (IBM SPSS, version 23.0). Statistical significance was set at $P<0.05$.

RESULTS

Muscle Oxygenation

Muscle oxygenation represented data from twenty-six subjects. TTM revealed that muscle oxygenation was statistically significant higher in muscle oxygenation after received TTM period than control group 4.43% (79.47±9.24%, 75.04±10.68%; P<0.05 respectively). However, when both of them received MIVC exercise, both TTM and control groups tend to be statistically significant lower in muscle oxygenation (P<0.05) comparing to after received intervention period. Moreover, in recovery period after subjects received MIVC exercise protocol, they showed higher muscle oxygenation of both groups comparing to resting period. However, TTM tended to be higher in recovery muscle oxygenation than control groups without statistical significance (Tab. 1 and Fig.3).

Time to Fatigue

Time to quadriceps muscle fatigue in TTM group (8.74±2.68 min.) was increased to 0.92 min comparing with control group (7.82±1.79 min). However, there was not statistically significant (P >0.05) between groups (Fig.4).

Quadriceps Muscle Force

The highest quadriceps muscle force tended to increase in TTM group (2727.50±860.84 N.) to 156.60 N. comparing with control group (2570.90±669.64 N.), but it was not statistically significant. In addition, the fatigue quadriceps muscle force was higher in TTM (1334.37±449.12 N.) than control group (1218.96±248.42 N.), but it was not statistically significant (Tab.1).

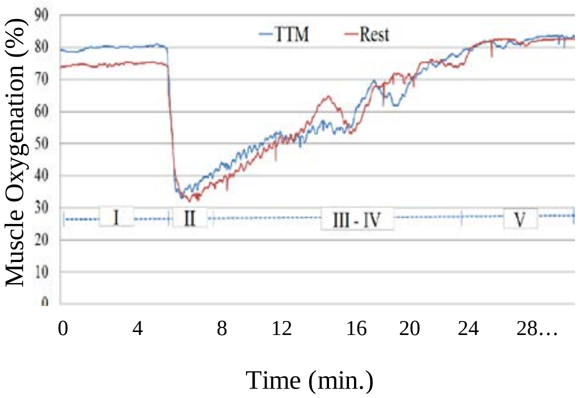

Fig. 3 The mean value of vastus lateralis muscle oxygenation levels (n=26) after received intervention (I), highest muscle force period (II), continuous MVIC to fatigue muscle force period (III-IV), and recovery period (V).

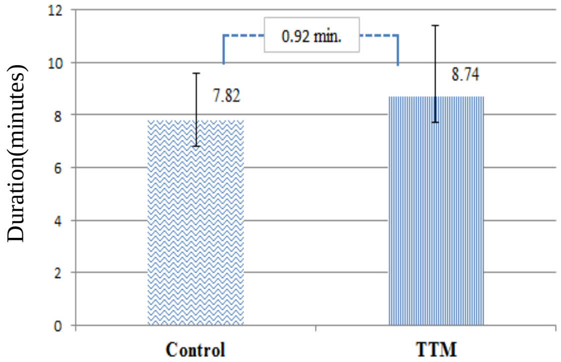

Fig. 4 Time to fatigue between TTM and control group (n=26)

DISCUSSION

TTM affects many mechanisms such as mechanical pressure on tissues (increased muscle compliance, ROM, and decreased tissue adhesion) [1] and changes tissue circulation (increased skin and muscle blood flow) described by physiological effects [33]. This investigation evaluates the possible increased muscle oxygenation, time to fatigue, and muscle force.

Influence of TTM can stimulate both skin and muscle blood circulations measured by laser Doppler flow meter. However, this effect is thought to help enhance muscle oxygenation which is measured by NIRS. The present study shows significant increase of muscle oxygenation in period of after received intervention 4.43% after receiving TTM for one hour. This result is consistent with previous studies [1], [33], and it is supported by physiological mechanism. After massage, local heating increases and results in hyperaemia of skin and intramuscular temperature, so O_2 circulated with hemoglobin into myoglobin may be higher. The present study also reveals higher level of muscle oxygenation which agrees with previous studies [3], [4], [6], [9], [33]. Conversely, the study of Weerapong [33] shows that there could be several possible mechanisms such as psycho physiological, biomechanical, and neurological effects. Besides, the result shows that during MVIC exercise at highest muscle force period of both TTM and control group, muscle oxygenation is rapidly lower and gradually increases reversing with the decrease of muscle force until recovery period which tends to be higher in muscle oxygenation comparing to after received intervention period. The present study is different from the study of Murthy [19]in case of measurement method of the muscle contraction amplitude. Murthy uses electrical muscular stimulation, but compression to vascular cannot be seen, so it can lead to positive correlation between muscle oxygenation and muscle force. Nevertheless, the present study discovers negative correlation between muscle oxygenation and muscle force. This can be described that measurement method implemented in the study has an effect on IMP increases during MVIC exercise that affects mechanical compression of local blood vessel resulting from force of contraction going up that causes an increase in the capillary perfusion. Thus, fluid from the vascular space gets into the interstitial tissue resulting in the increase of IMP [11], [12]. Moreover, MVIC leads to hypoxic condition that causes the decrease of arterial oxygen content (CaO_2). As a result, hypoxic sensor such as endothelium cells, vascular smooth muscle cells, and RBC is stimulated to produce NO and PGs, so higher blood flow and muscle oxygenation was found in recovery period. In addition, in recovery period of TTM group tends to get higher than control group because massage can stimulate the creation of NO, and it is possible to decrease IMP. Nevertheless, further study should be carried on [34], [35].

Time to localized muscle fatigue of TTM group is longer than control group for 0.92 min. that can be seen from muscular acidity. In other words, during isometric exercise, anaerobic respiration is stimulated and inorganic phosphate (P_i) including hydrogen ions (H^+) are produced influencing acidity of blood and muscle cells [14]. Moreover, this acidity slow down enzyme activity, and muscle is aggravated that can lead to nerve ending, pain, and irritation of the central nervous system [14]. On the contrary, the present study shows increased muscle oxygenation that reduces the acidity of the muscle cells. In other words, when O_2 in both blood concentration and muscle oxygenation increases, bicarbonate (HCO_3^-) also increase at the same time, so acidity is lower. This is the theory clarifying that fatigue can be delayed, and exercise can be continuously carried on. However, there is no statistical significance for time to localized muscle fatigue. Also, local muscular fatigue protocol may be inappropriate, so different metabolic demands are imposed.

Highest quadriceps muscle force increases to 156.60 N. after TTM, but there is no statistical significance. However, the increase of muscle force can be explained by physiological effect that massage can increase blood circulation and oxygen delivery to working muscle. Additionally, it can decrease metabolic waste products from anaerobic respiration [33]. On the other hand, during MVIC, metabolic waste products is produced metabolize from anaerobic respiration such as P_i, H^+ and lactic acid. This metabolite is stored within the muscle cells where the P_i is allowed to bind to Ca^{2+} and precipitate, respectively. As a result, Ca^{2+} is decreased, and cross-bridge turnover is decreased, eventually [15].

Table 1 the comparisons of muscle oxygenation, muscle force, and time to fatigue between control and TTM group.

Outcome	Seq.	Period 1 Mean ± SD	Period 2 Mean ± SD	Effect size	95% Conf. Interval	*P*
Mo_2 after received INT.	1	77.66±9.95	77.46±11.19	I (-4.62) II (0.31) III (-4.43)	(-8.10 to -1.14) (-3.38 to 4.00) (-7.91 to -1.90)	0.01* 0.86 0.01*
	2	81.48±7.28	72.42±11.41			
Mo_2 of highest force	1	25.75±23.52	24.91±20.37	I (-4.50) II (-3.38) III (0.38)	(-10.12 to 9.22) (-12.04 to 5.27) (-9.29 to 10.05)	0.92 0.42 0.94
	2	32.14±26.36	32.07±26.26			
Mo_2 of fatigue force	1	48.83±27.42	50.33±22.82	I (-1.54) II (-3.60) III (-3.04)	(-7.18 to 4.10) (-12.96 to 5.76) (-8.68 to 2.61)	0.57 0.43 0.28
	2	59.07±23.62	54.50±22.49			
Mo_2 of recovery	1	83.83±7.04	83.25±7.46	I (-2.26) II (-0.14) III (-1.67)	(-5.49 to 0.98) (-2.35 to 2.07) (-4.91 to 1.56)	0.16 0.90 0.30
	2	85.79±5.06	81.86±7.28			
Highest muscle force	1	2527.39±599.57	2747.95±613.80	I (63.96) II (-11.54) III (-156.6)	(-163.22 to 291.14) (-318.32 to 295.24) (-383.78 to 70.58)	0.57 0.94 0.17
	2	2707.06±1107.88	2614.42±739.70			
Fatigue muscle force	1	1222.52±230.60	1347.71±427.40	I (9.78) II (8.45) III (-115.41)	(-140.18 to 159.75) (-119.40 to 136.30) (-265.37 to 34.55)	0.90 0.90 0.12
	2	1321.034±70.84	1215.40±266.23			
Time to Fatigue	1	7.56±2.21	8.90±2.65	I (0.41) II (-0.06) III (-0.92)	(-0.83 to 1.65) (-0.77 to 0.66) (-2.16 to 0.33)	0.50 0.88 0.14
	2	8.59±2.70	8.08±1.37			

Abbreviations: INT.; Intervention, I; Period effect, II; Carryover effect and III; Treatment effect
Note: The data were presented using mean ± SD which were analyzed by cross analysis (method of Alman DG.).
**P*<0.05

CONCLUSION

This study evaluated the effects of TTM on muscle oxygenation, time to fatigue, and muscle force. The results show that TTM increases muscle oxygenation after received intervention period, and it seems prolong duration of time to fatigue and higher muscle force. It would be interesting to characterize the effect of TTM for boxing, tennis or endurance exercise and to analyze its possible influence on muscle oxygenation, time to fatigue, and muscle force in the subsequent performance.

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