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Assessments of forearm muscular demands and perceived exertions for different massage techniques of the Swedish-type massage

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ABSTRACT

Work-related musculoskeletal disorders (WRMSDs) in massage practitioners is prevalent due to physically demanding nature of massage practice. Given that changes in massage techniques may occur over the course of a day to accommodate for fatigued muscles and the use of proper techniques may also be compromised with fatigue to the musculature of the upper extremity, research regarded the effects of different massage techniques on muscular demands needed to be further explored. In this study, nine male participants performed four Swedish-type massage techniques including effleurage, petrissage, tapotement, and friction on a same client. The muscular demands for different techniques were assessed with surface EMG positioned over four forearm muscles of dominant arm including flexor digitorum superficialis, flexor carpi radialis, extensor carpi radialis longus, and extensor digitorum. Perceived exertions were also collected for different techniques using Borg CR 10 scale. The results indicated that there are significant differences among forearm muscle and massage technique on muscular demands. Similar massage technique effects on perceived exertions were also observed in current study. In addition, there is statistically significant interaction effect between forearm muscle and massage technique on muscular demands. To reduce muscular load which is a potential risk factor associated with the development of WRMSDs based on the results of this study, the time to perform friction and tapotement techniques during a massage session could be extended to prevent overexertion of muscular demands required for the petrissage and effleurage techniques.

Keywords: Work-related Musculoskeletal Disorders (WRMSDs), Swedish-type massage, Massage technique, Muscular demand, Perceived exertion.

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1. INTRODUCTION

Massage therapy is a commonly used treatment for symptoms such as elderly dementia, sports injuries, and musculoskeletal pain-related conditions for a variety of purposes such as injury prevention, pain reduction, spasms reduction, fatigue recovery, relaxation, health enhancement, performance improvement (Gönenç et al., 2020; Hemmings 2001; Kerautret et al., 2020; Reese 2002; Sundberg et al., 2017). However, work-related musculoskeletal disorders (WRMSDs) in massage practitioners is prevalent due to physically demanding nature of massage practice. Albert et al. (2008) surveyed 502 registered massage therapists across Canada to determine the prevalence of musculoskeletal pain and discomfort to the low back, shoulders, neck, wrist and thumbs associated with therapeutic treatments. The highest rates of pain and discomfort was reported in the wrist and thumb (80%), followed by the low back (65%), neck and shoulders (64%). Among 444 Thai traditional massage therapists, the frequently reported body parts associated with WRMSDs pain were the right hand (24.5%), the left hand (23%), and the right shoulder (18.9%) (Chumnanya et al., 2013). In Taiwan, Jang et al. (2006) indicate that71.4% of 161 visually impaired massage practitioners had at least one work related musculoskeletal disorder in 12 months. The prevalence rates of WRMSDs were reported in finger or thumb (50.3%), shoulder (31.7%), wrist (28.6%), neck (25.5%), arm or elbow (23.6%), forearm (20.5%), and back (19.3%), respectively. Lee et al. (2017) also show that in a 12-month period, 89.5% of 200 visually impaired Taiwan massage practitioners had musculoskeletal complaints. The prevalence rates of WRMSDs were recorded in lower back, shoulder, and hand/wrist were 65.9%, 64.8%, and 62.6%, respectively. The high prevalence of WRMSDs among massage practitioners indicate that musculoskeletal disorders (MSDs) are important health and safety issues which should be controlled in the work environments.

Swedish-type massage, developed by Per Hendrik Ling (1776-1839), is the most widely taught and practiced style of relaxation massage used around the world which employs five basic manual techniques (strokes): effleurage (gliding), petrissage (kneading and lifting), friction (moving the tissue layers underneath the skin), vibration, and tapotement (percussion) (Elibol and Cavlak, 2019; Mahardika 2017; Sherman et al., 2006; Weerapong et al., 2005). Effleurage is a mild massage technique consisting of gliding or sliding movement over the skin with a smooth continuous motion (Tappan and Benjamin, 1998). Petrissage is defined as lifting, wringing, or squeezing of soft tissues in a kneading motion, or pressing or rolling of the tissues under or between the hands (Tappan and Benjamin, 1998). Friction used accurately delivered pressure applied through the fingertips or palm to reduce muscle spasm or break up adhesions from old injuries (Goats, 1994). Vibration is a type of massage administered by quickly tapping with the fingertips or alternating the fingers in a rhythmic manner or by a mechanical device (Glanze et al., 2009). Tapotement is a technique using various parts of the hand striking the tissues at a fairly rapid rate (De Domenico, 1997). In terms of application, the effleurage movements are usually applied on the beginning of a session, during a break after applying a specific technique, and on the end of each session. The petrissage technique is applied following effleurage. Friction technique is used for a specific purpose such as to reduce muscle spasm. Vibration movements are used toward the end of the treatment. In addition, tapotement is used before and during a competition (sports) or in finishing a section of the body (Weerapong et al., 2005).

Currently, research investigating massage profession has focused on providing empirical evidences for the benefits of massage therapy as a treatment. For example, positive effects of massage therapy have been found on relieving symptom (e.g. pain, fatigue, anxiety, etc.) for cancer patients (Lopez et al., 2017; Moraska et al., 2010; Wilkinson et al., 2008). Massage therapy also shows evidences to manage a range of musculoskeletal pain such as low back pain, neck and shoulder pain, and chronic pelvic pain (Elibol and Cavlak, 2019; Xu et al., 2015). In addition, massage therapy has been used to relieve labour pain and increase satisfaction with delivery (Gönenç et al., 2020) and to treat myalgia in Covid patients (Rajurkar et al., 2021). By contrast, little attention has been paid to explore risk factors associated with the occurrence of WRMSDs among the massage practitioners. Massage practitioners conduct massages for a couple of hours each day and a treatment typically last between 30 minutes and 90 minutes (Albert et al., 2006; Buck et al., 2007; Jang et al., 2006). During a massage session, massage practitioners apply different manual techniques including touch, gliding, friction, kneading, vibration, and percussion to the muscles of the body to facilitate circulation, and to relieve muscular tension and musculoskeletal pain (Jang et al., 2006; Loving 1999). Massage also involves the use of many body regions, with constant movement in awkward positions and with repetitive and forceful use of the forearms, wrists, hands, fingers, and thumbs (Anderson, 2018; Fritz, 2000; Greene, 1995; Yoopat et al., 2018). Most of the effort exerted during massage is sustained, restrained, and somewhat static, with pressure focused downward to deliver compressive force (Fritz, 2000). All of these elements (e.g. long duration exposure, forceful exertions, awkward postures, and repetition etc.) may lead to higher muscular loads which are potential risk factors associated with the development of WRMSDs (Chumnanya et al., 2013; Fritz, 2000; Greene, 1995; Yoopat et al., 2018).

To date, four studies had used electromyography (EMG) and/or biomechanical model (3D rigid link static model) to measure the muscular demands on the upper extremity and/or lower back of the massage practitioners (Albert et al., 2006; Buck et al., 2007; Smith et al., 2009; Yoopat et al., 2018). In Albert et al.'s (2006) study, hand forces were used as input to a 3D static biomechanical model to determine low back loads (in Newton). The peak lumbar compression and shear loads measured for different massage techniques at the L4/L5 segment ranged from 1173.5 to 1713.9 N and 0 to 78.2 N, respectively. These loads are lower than the risk threshold values of 3400 N and 500 N for compression and shear values, respectively (Albert et al., 2006). Buck et al. (2007) determined the difference in muscular demands of performing 10-minute regional back manual therapy using a massage chair and a massage table. The root mean square (RMS) value of electromyography (EMG) signals was integrated over the whole massage session to represent the mean activation from anterior deltoid, posterior deltoid, upper trapezius, middle trapezius, lumbar erector spinae, flexor carpi radialis, and extensor carpi radialis muscle groups. Their results found higher activation (RMS) for lumbar erector spinae for massage done on a massage table. However, muscular demands presented as percentage of maximal voluntary contraction (%MVC) were not calculated. Smith et al. (2009) compared the muscular loads (%MVC) of five shoulder muscles among single-arm technique (SAT), double-arm technique (DAT), and treatment-tool technique (TTT) when applying 20 Kg force by elbow on artificial contacts surface. The mean muscular demands (28.5%MVC) of SAT were greater than DAT (17.3%MVC) and TTT (10.2 %MVC). Yoopat et al. (2018)

showed that the muscular demands for the trapezius and deltoids muscles were < 15%MVC (within safe levels of work) for Thai traditional massage practitioners.

As stated above, high prevalence of WRMSDs were reported mostly on the lower back and upper extremity among massage practitioners. However, previous studies showed that the lumbar loads and muscular demands determined at L4/L5 segment and shoulder and upper arm muscles (trapezius and deltoids) were relatively low compared to the safety threshold values for massage practitioners. Therefore, research evaluating the muscular demands for forearm muscles that may lead to WRMSDs when performing massage therapy needed to be further explored. Since none of previous studies discussed the effects of different massage techniques on muscular demands of massage practitioners. The Bureau of Labour Insurance (BLI) of Taiwan also showed that the ratios of Workers' Compensation (WC) claims for WRMSDs in "neck and upper extremity" accounted for 75.9%, 78.9%, 75.0%, 75.1%, and 78.0% of all WRMSDs claims for the years 2017 to Jan.-Aug. of 2021 (BLI, 2021). Given that changes in massage techniques may occur over the course of a day to accommodate for fatigued muscles and the use of proper techniques may also be compromised with muscle fatigue (Jang et al., 2006), the effects of different massage techniques on muscular demands especially in forearm muscles for Swedish-type massage will be evaluated in this study.

2. METHODS

2.1 Subjects

Nine volunteered right-handed males free of MSDs in the upper extremities comprised the subject pool. The subject's free of MSDs status in the upper extremities was identified through interviewing during the recruiting process. The mean values of age, height, and Body Mass Index (BMI) are 23.3 ± 1.6 years, 175.1 ± 3.3 cm, and 26.9 ± 5.7 Kg/m^2, respectively. All nine subjects participated and completed the simulating massage tasks in the laboratory while none were professionally involved in massage practices. In addition, this study was approved by the Institutional Review Board for Ergonomics Experiment of Chao Yang University of Technology and each participant has signed the informed consent document.

2.2 Grip Strength Measurement

Greene (1995) hypothesized that hand strength is associated with WRMSDs in massage practitioners. Jang et al. (2006) show that although mass grasp (grip) and lateral pinch were not associated with upper-extremity WRMSDs, visually impaired massage practitioners with small values for these strengths tended to have an increased prevalence of WRMSDs. In this study, maximum voluntary contraction (MVC) grip strength was measured for each participant using a Jamar grip dynamometer (Lafayette Instrument Company). The strength of a linear association between grip strength and muscular load was also evaluated in this study.

2.3 Muscular Demands Measurement

An EMG system (BIOPAC MP150) were used to collect and process the EMG signals. Surface EMG electrodes (SX230, Biometrics Ltd., UK) were positioned over the following four forearm muscles of dominant arm: (1) flexor digitorum superficialis (FDS), (2) flexor carpi radialis (FCR), (3) extensor carpi radialis longus (ECR), and (4) extensor digitorum (ED) of the subject's dominant arm. These muscles groups were chosen for their relevance with flexion and extension movements of fingers, thumb, and wrist where highest prevalence rates of pain and discomfort were reported (Albert et al., 2008; Jang et al., 2006) and for the ability of the researchers to position surface electrodes over muscle bellies (Tixa, 2015). A ground electrode was also placed at the lateral epicondile of the subject's dominant arm. The EMG signals were bandpass filtered (20-450 Hz) and pre-amplified (gain: 1000) with 1k Hz sampling rate.

The percentage of maximal voluntary contraction (%MVC) calculated using equation 1 for each muscle represented the muscular demand of that muscle.

$$\%\ \mathrm{MVC} = \frac{\mathrm{RMS_{massage}} - \mathrm{RMS_{rest}}}{\mathrm{RMS_{MVC}} - \mathrm{RMS_{rest}}} \quad (1)$$

The $\mathrm{RMS_{massage}}$、$\mathrm{RMS_{rest}}$、and $\mathrm{RMS_{MVC}}$ are the root mean square (RMS) values of the entire massage session、the rest condition sampled for 2 minutes before starting of the massage session、and the maximum voluntary contraction of each muscle for 5 seconds.

2.4 Perceived Exertion

Besides adopting objective technique (EMG) to measure muscular demands, common subjective assessment tool Borg CR 10 scale (Borg, 1982) was used in this study to record perceived exertions for different massage techniques. Borg CR 10 scale was selected since it has been previously asserted as a reliable tool with measurement errors of approximately 6% (Borg, 1998) and sensitive to changes in physical task demands (DiDomenicoa and Nussbaum, 2008). At the end of each massaging trial, the subject provided a rating of perceived exertion using the Borg CR 10 scale between 0 and 10 with verbal anchors (e.g. 0: nothing at all; 5: strong; 10: extremely strong) for subjectively evaluation of perceived exertion.

2.5 Experiment Procedure

The MVC grip strength datum and the anthropometry datum of the participant were first measured using Jamar grip dynamometer. Each subject applied a steady exertion sustained for four seconds with testing postures described by Sung (2014). Three replications within 10% tolerance were recorded and averaged as the MVC grip strength. At least two-minute rest period was provided between exertions. The basic anthropometric measurements including height, weight, and four hand dimensions (hand length, maximum breadth of hand, forearm length, and arm length) were performed using Martin-type anthropometer, scale, digital caliper, and tape measure for each subject. The hand dimensions were measured for each subject following instruction described by Sung et al. (2015).

Then, each participant attended two 2-hour testing sessions on two days separated by at least 24 hours. Four Swedish-type massage techniques, namely effleurage, petrissage, friction, and tapotement were randomly assigned to sessions 1 and 2 (two techniques in one session). The vibration technique is not included in this experiment since it may involve the use of mechanical device. The participants were trained 6~8 hours by one massage practitioner to perform the four Swedish-type massage techniques before starting the testing sessions. In each hour of each session, the subject performed three 10-minute back massaging trials with the same assigned technique on a same client with 10-minute break between trials. At the end of each trial, the researcher orally asked the subject to provide a rating score of perceived exertion using the Borg CR 10 scale. Jang et al. (2006) indicated that the "inappropriate work height" was related to the prevalence of spinal WRMSDs, therefore, the table height in this experiment was adjusted for each participant to perform simulated massaging tasks in comfortable standing posture. Fig. 1 and Fig. 2 show a subject performed effleurage and petrissage back massages on a client.

Fig. 1. The subject performed effleurage technique on a client

Fig. 2. The subject performed petrissage technique on a client

2.6 Statistical Analysis

The independent variables are four forearm muscles and four massage techniques. The performance measures are muscular load (EMG parameter %MVC) of the four muscles and perceived exertion (Borg CR-10 rating score). Repeated measures analysis of variance (ANOVA) with were used in this study to determine whether there are significant differences between independent variables on dependent variables. The Pearson product-moment correlation coefficient (r) was used to measure the strength of a linear association between muscular load, grip strength and age, height, BMI, and hand dimensions. All data were analyzed for statistical significance with cut-off value α=0.05 using the SPSS 18 (SPSS Inc, Chicago, Illinois) statistical software.

3. RESULTS

Table 1 shows the mean values and standard deviations of hand length, maximum breadth of hand, forearm length, arm length, and MVC grip strength of these nine subjects. The mean MVC grip strength 413.8 Newton measured for these nine males with ages ranging from 21-25 years are consistent with the normative data range recorded by Bohannon et al. (2006). Table 2 shows the means and standard deviations of muscular loads of two trials for four muscle groups when performing four massage techniques. Table 3 shows the means and standard deviations of perceived exertions (Borg CR 10 rating scores) subjectively reported by the subjects when performing four massage techniques.

Since one-way analysis of variance indicates that there are no statistically significant differences of trial effect on muscular loads ($F = 0.182$, $p = 0.834$), the average muscular loads of two trials were used for analysis. Table 4 contains the repeated measures ANOVA results for the effects of forearm muscle, massage technique, and their interaction on muscular load (%MVC). The results indicate that there are significant differences among forearm muscle ($F = 10.67$, $p < 0.0001$) and massage technique ($F = 16.90$, $p < 0.0001$) on muscle loads. In addition, there is statistically significant interaction effect between forearm muscle and massage technique ($F = 33.46$, $p < 0.0001$) on muscle loads.

Fisher's Least Significant Difference (LSD) pairwise comparisons of forearm muscle effect indicate that there were statistically significant differences between ECR vs. the other three muscle groups ($p < 0.005$). The muscle loads on the ECR muscle groups are 27.8%MVC, 19.4%MVC, and 19.6%MVC lower than the FDS, FCR, and ED muscle groups, respectively. LSD pairwise comparisons of massage technique effect show that there were statistically significant differences between massage techniques. When performing petrissage massage, the muscle loads are 9.5%MVC, 18.1%MVC, and 14.3%MVC greater than effleurage, friction, and tapotement techniques ($p < 0.05$), respectively. In addition, the muscle loads for effleurage massage are 8.6%MVC and 4.8%MVC higher than friction and tapotement ($p < 0.05$) massages.

Fig. 3 shows the plot of the significant interaction effect between forearm muscles and massage techniques. The muscular loads on the ECR are significantly lower ($p < 0.05$) than those on the other three muscles when performing effleurage massage. For petrissage massage, the muscular loads on the FDR and FCR muscles are significantly higher ($p < 0.05$) than the ED and ECR muscles. When conducting friction massage, the muscular loads on the FCR and ECR muscles are significantly lower ($p < 0.05$) than the ED muscle. In addition, the muscular loads on the FDR, FCR, and ECR muscles are significantly lower ($p < 0.05$) than the ED muscle for tapotement massage.

For the effects of massage technique on subjective perceived exertion, the ANOVA results show significant differences among massage techniques ($F = 196.41$, $p < 0.0001$) on Borg CR-10 rating score. Post hoc LSD pairwise comparisons of massage technique effect indicate that the perceived exertion ratings when performing petrissage massage are 1.67, 3.08, and 3.25 greater than effleurage, friction, and tapotement techniques ($p < 0.05$), respectively. In addition, the perceived exertion ratings for effleurage massage are 2.42, and 2.58 higher than friction and tapotement ($p < 0.05$) massages. Similar trend between perceived exertions assessed using Borg CR 10 scale and muscular demands for flexor muscles (FDS and FCR) were also observed across these four techniques of Swedish-type massage (Fig. 4).

Pearson correlations (r) between muscular load (%MVC) and 8 variables (age, MVC grip strength, and 6 anthropometric measures) and between MVC grip strength and 8 variables (age, muscular load, and 6 anthropometric measures) were shown in Table 5. Adopting Portney and Watkins's (2008) guidelines for interpreting strengths of correlations, Weight, hand length, and maximum breadth of hand showed moderate to good relationships (0.50 to 0.75) while height and arm length showed fair relationships (0.20 to 0.50) with MVC grip strength. No significant correlations between muscular load (%MVC) and 8 variables were found in this study.

Table 1. The mean values and standard deviations of four hand dimensions and MVC grip strength of nine male subjects

Hand dimensions / Grip strength	Mean	SD
Hand length (cm)	19.0	1.0
Maximum breadth of hand (cm)	10.5	0.6
Forearm length (cm)	46.5	1.4
Arm length (cm)	77.3	2.8
MVC grip strength (N)	413.8	94.4

Table 2. The means and standard deviations of muscular loads of four muscle groups when performing four massage techniques

Technique / Muscle Group	FDS		FCR		ECR		ED	
	Mean (%MVC)	SD	Mean (%MVC)	SD	Mean (%MVC)	SD	Mean (%MVC)	SD
Effleurage	44.20	20.39	31.40	14.07	14.57	8.65	39.95	17.64
Petrissage	72.04	36.71	68.48	31.25	7.67	1.72	19.87	7.52
Friction	28.17	29.35	15.38	8.21	16.63	6.85	35.56	14.54
Tapotement	26.36	20.67	21.66	14.32	20.59	11.32	42.36	9.00

FDS: flexor digitorum superficialis; FCR: flexor carpi radialis; ECR: extensor carpi radialis longus; ED: extensor digitorum

Table 3. The means and standard deviations of perceived exertions (Borg CR-10 rating scores) when performing four massage techniques

Technique/ Borg Rating	Mean (Borg CR-10 Rating)	SD
Effleurage	7.67	1.14
Petrissage	8.33	0.97
Friction	5.25	0.58
Tapotement	5.08	0.62

Table 4. Repeated-measures ANOVA results for the effects of forearm muscle, massage technique, and their interactions on muscular load

Source	SS	Df	MS	F	Sig
FM	71231.70	3	23743.90	10.67	0.0000
MT	31175.98	3	10391.99	16.90	0.0000
FM x MT	114928.82	9	12769.87	33.45	0.0000

FM: forearm muscle; MT: massage technique

Table 5. Pearson correlations (r) between muscular load and MVC grip strength and variables

Variables	Muscular Load (%MVC)		Grip Strength (N)	
	Pearson's r	Sig. (2-tailed)	Pearson's r	Sig. (2-tailed)
Age	0.088	0.394	0.186	0.070
Height (cm)	0.153	0.136	0.203	0.047
Weight (Kg)	-0.014	0.896	0.560	0.000
Hand length (cm)	0.065	0.528	0.733	0.000
Maximum breadth of hand (cm)	-0.008	0.938	0.549	0.000
Forearm length (cm)	0.109	0.293	-0.158	0.124
Arm length (cm)	0.090	0.386	-0.468	0.000
Muscular Load (%MVC)	---	---	-0.006	0.954
Grip Strength (N)	-0.006	0.954	---	---

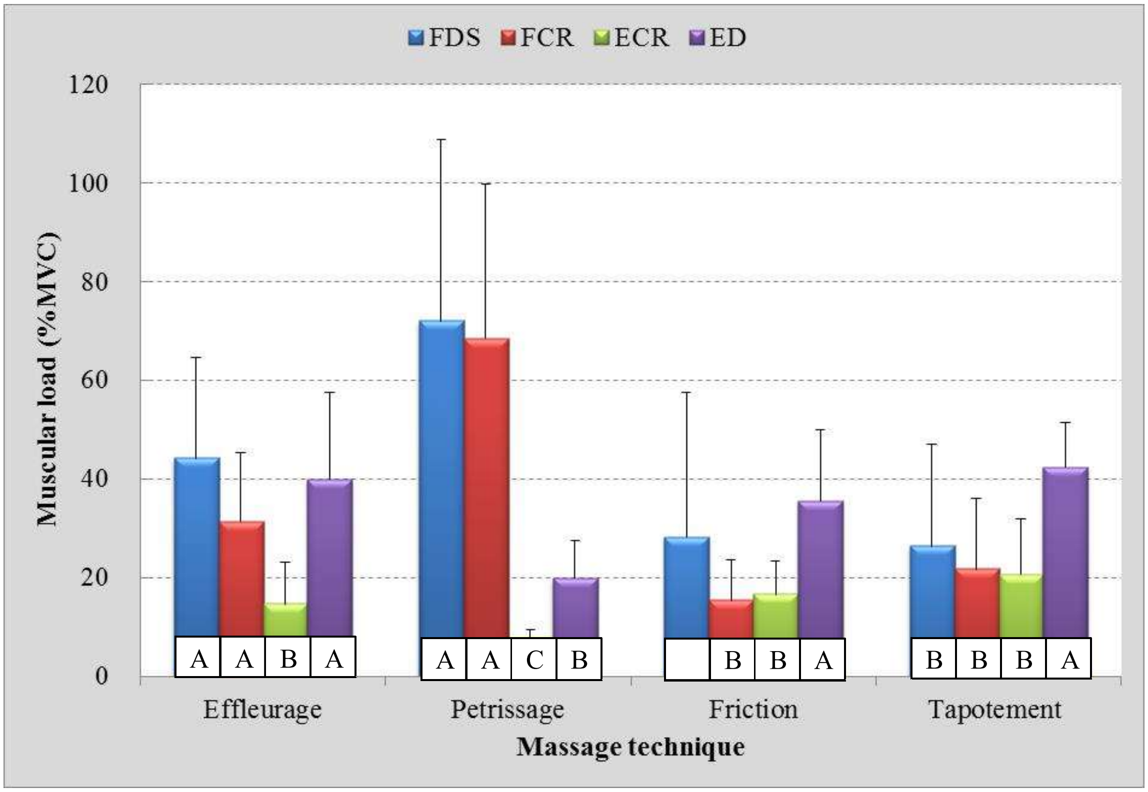

Fig. 3. The significant interaction effect between forearm muscle and massage technique on the muscular loads

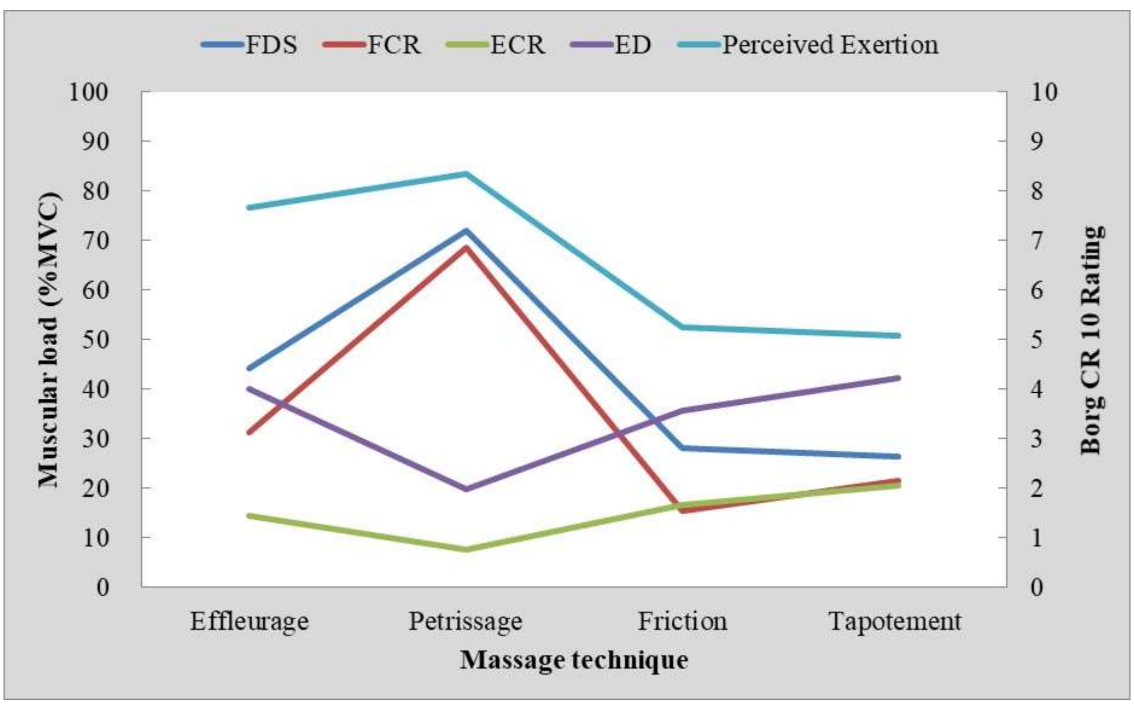

Fig. 4. Trend for average muscular loads measured for four muscles and average perceived exertions across different Swedish-type massage techniques

4. DISCUSSION

The client lay on his stomach when the participant stood in the head direction performing effleurage massaging on his back (Fig. 1.). When conducting massage with the other three techniques, the participant stood on the right side of the client (Fig. 2.). Collecting EMG signals unilaterally on the right side of the client was appropriate as stated by Buck et al. (2007) while all the participants recruited in this study are right-handed and both hands performed the same movements together or alternating performed the same movements with his right and left hand.

This study investigated the effects of four different techniques of the Swedish-type massage on the muscular demands of the forearm muscles. As expected, the results indicate that the muscular loads on the forearm muscles were significantly affected by the massage techniques. The muscular loads measured for performing petrissage technique are higher than the other three techniques. In addition, muscle loads for performing effleurage massage are higher than friction and tapotement massages. The reason may due to the natural of the massage techniques. Petrissage massage required the participants to knead, squeeze, wring, and lift the back muscles and soft tissues of the client (Tappan and Benjamin 1998). Flexing the fingers and thumb firmly and repeatedly together increased the muscular loads especially on the flexor digitorum superficialis (FDS) and flexor carpi radialis (FCR) muscles (Fig. 3). Effleurage massage required the participant to glide and slide his hands over the back of the client with a smooth continuous motion (Tappan and Benjamin 1998). Gliding/sliding hands away from the participant extended the digits, therefore, increased the loads on the extensor digitorum (ED) muscle group. In addition, flexor digitorum superficialis (FDS) and flexor carpi radialis (FCR) muscles were activated while gliding/sliding hands close to the participant. When performing friction and tapotement massages, muscle groups of shoulders and upper arms may also be used (not measured in this study) while using fingertips or palm to applied pressure or various parts of the hand (e.g. thenar or hypothenar) to strike on the back of the client (Goats 1994, De Domenico 1997). Accordingly, muscular demands for petrissage technique are greater than those of the other three techniques while muscular demands for effleurage technique are greater than those of friction and tapotement techniques.

DiDomenicoa and Nussbaum (2008) used Borg CR-10 scale to assessed perceived exertions for weight-lifted tasks with 0%, 8%, 14&, and 20% of body mass. Their results indicated that Borg CR 10 ratings were significantly correlated (r=0.80) with the physical task demands. In this study, the physical task demands for each massage technique were represented by measured muscular demands of four muscle groups. Therefore, direct correlation between physical task demands of massage technique and perceived exertion cannot be performed since the %MVC measured from different muscle groups cannot be summed up to represent a single physical task demand for each technique. However, similar massage technique effects on perceived exertions as on muscular demands were also observed in current study. Subjective Borg CR-10 scale assessments show that perceived exertions for petrissage technique are greater than those of the other three techniques while perceived exertions for effleurage technique are greater than those of friction and tapotement techniques. These similar effects indicate that easy to use subjective assessment tool could be adopted to evaluate the physical demands with minimal interference for massaging tasks (DiDomenicoa and Nussbaum 2008).

For the forearm muscle effect, this study found that the muscular loads on the ECR muscle groups are 27.8%MVC, 19.4%MVC, and 19.6%MVC lower than those of the FDS, FCR, and ED muscle groups. The reason may also due to the natural of the massage techniques while none of the four techniques required extending the thumb (radial side of the hand) for most of the time during massaging sessions. As for the interaction effect, when conducting petrissage massage, the participants were required to flex the fingers and thumb together and exerted a great amount of forces on the soft tissues or muscles on the back, therefore, the muscular demands on the flexor muscle groups (FDS and FCR) are significantly greater than the extensor muscle groups (ECR and ED). Similar effects were found for effleurage massage where the muscular demands on the FDS and FCR muscles are greater than the ECR muscle. In addition, the force exerted by the ED muscle were also greater than the ECR muscle while extending digits during effleurage massage movements increased the muscular demands. On the other hand, the muscular demands on the FCR and ECR muscles and FDR, FCR, and ECR muscles are lower than the ED muscle when conducting friction and tapotement massages, respectively. Higher muscular demands on the ED muscle for these two techniques may result from the extension requirements of the digits.

To prevent muscle fatigue for hand activities involving hand tools, Armstrong et al. (2002) summarized several studies and their recommended exposure limits for muscle activities are 15%MVC and 15% to 21%MVC for continuous exertions and intermittent exertions, respectively. In present study, the muscular loads (%MVC) measured for all forearm muscles are above the 15~21%MVC limit except for the ECR muscle when performing effleurage (14.6%MVC) and petrissage (7.7%MVC) massages. However, it is still inadequate to estimate the possibility to induce WRMSDs or potential harm since the exposure limits recommended are for hand activities involving hand tools. In addition, little evidence was found in the literature to suggest the threshold value(s) of muscular loads to prevent the occurrence of muscle fatigue or MSDs. Supporting epidemiological evidences are required to establish the potential associations between %MVC values and risk factors contributed to MSDs. Comparing with Yoopat et al.'s (2018) study, the muscular loads determined for Thai traditional massage practitioners were less than 15%MVC on the trapezius and deltoids muscles. The differences in muscular demands may attribute to gender, experience (trainee versus professional), group of muscles (forearm versus upper and shoulder), and type of massage (Swedish versus Thai) performed in these two studies. For the other three studies (Albert et al. 2006, Buck et al. 2007, Smith et al. 2009) observing the muscular loads on the massage practitioners' upper extremities and lower back, comparisons could not be made with current study since compression/shear loads and muscle activity in RMS values instead of %MVC values were reported.

This preliminary study recruited college students, with 6~8 hours training by one massage practitioner, as participants to conduct on-site Swedish-type massage. Since muscular load is a potential risk factor associated with the development of WRMSDs (Fritz 2000, Greene 1995), more experienced massage practitioners should be recruited to better understand the muscular demands required for different techniques. In addition, females and more muscle groups including upper arm, shoulder, and back muscles could be included to better understand the muscular demands for the massage practitioners when performing massage therapies.

5. CONCLUSION

The participants exerted a great amount of force (except the ECR muscle when performing effleurage and petrissage massages) when performing each of the Swedish-type massage techniques. For the four massage techniques, petrissage technique resulting in highest muscular demands of the forearm muscles followed by effleurage technique. The muscular demands measured for friction and tapotement techniques are significantly lower than petrissage and the effleurage techniques. Similar massage technique effects on perceived exertions were also observed in current study. The muscle loads on the ECR muscle groups are lower than the other three muscle groups. Significant interaction effect between forearm muscles and massage techniques is also present in this study. To reduce muscular load which is a potential risk factor associated with the development of WRMSDs based on the results of this study, the time to perform friction and tapotement techniques during a massage session could be extended to prevent overexertion of muscular loads required for the petrissage and effleurage techniques. In addition, more experienced massage practitioners including females should be recruited to better understand the muscular demands required for different techniques to prevent overexertion of the practitioners and better the health and safety of the massage working environments.

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