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Investigating the Effects of Ogawa Master Drive AI Automated Massage on Blood Circulation and Sleep Quality

Ayan Paul[1], Khin Wee Lai[1,*], Juliana Usman[1], Mohd Yazed Ahmad[1], Mohafez Hamidreza[1], Hadizadeh Maryam[2], and Zhi Chao Ong[3]

[1]*Department of Biomedical Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia*
[2]*Centre for Sport and Exercise Sciences, Universiti Malaya, Jalan Universiti, 50603 Kuala Lumpur, Malaysia*
[3]*Department of Mechanical Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia*

Sleep and stress-related disorders are increasingly becoming more prevalent among adult population. Massage therapy (MT) may assist in improving the peripheral circulation through mechanical manipulation of soft tissues and passively act upon reducing stress stimuli as well as induce relaxation and sleep. For the purpose of evaluating the efficacy of massage chair therapy (MCT), this study is divided into two parts. First, 15 participants (mean age = (21.00 ± 2.00) years; body mass index (BMI) = (19.22 ± 2.23)) were enrolled in a randomized controlled, cross-over, repeated measures, and single-blinded trial on a pre and post treatment based session where skin blood flow (SBF) was measured. Except for the control mode ($p > 0.05$), all other mode variants exhibit significant increased SBF between pre-post sessions ($p < 0.05$). Furthermore, compared to the blood circulation and sweet dreams massage modes, deep tissue massage mode exhibited a significant increase in SBF values ($p < 0.05$). In the second part of the study, 5 participants (age 24.00 ± 3.00 years; weight 73.10 ± 5.63 kg; height 178.28 ± 10.08 cm; BMI 22.49 ± 1.89) underwent MCT with only sweet dreams mode. Richards-Campbell Sleep Questionnaire and wrist actigraph were used to assess pre- and post-treatment sleep quality. After undergoing massage all subjects showed improvement in overall sleep quality. These results are suggestive that the automated MCT may potentially improve blood circulation and promote relaxation and sleep.

Keywords:

1. INTRODUCTION

According to National Health and Morbidity Survey, the number of Malaysians with depression and anxiety disorder rose from 12% in 2011 to 29% in 2017 [1]. Stress, induced from myriad external factors, incites vascular response from the human body; both physical and emotional stress cause significant hemodynamic alterations in the body: vasculatures regulate normal blood flow by acting as intricate conduits supplying oxygen (O_2) and nutrient rich blood, and removing metabolic wastes from tissues [2]. In fact, elevated condition of stress causes higher levels of O_2 consumption and metabolic waste generation. Because the microcirculatory network (constituted by arterioles, capillaries, and venules) plays a vital role in replenishing tissues and recovering metabolic balance, if impaired, it can delay tissue regeneration and consequently add to stress related complications. Unlike arteries and veins—which are regulated involuntarily through nerve impulses and/or chemical signals—lack of receptors renders the microcirculatory network unaffected from such neurogenic alterations. However, tactile stimulation on skin surface can increase arteriolar pressure and muscle temperature, and thereby, augment blood flow [3, 4]. In fact, earlier research report that by alternatingly compressing and releasing body tissue, long manual massage stroke can promote local blood circulation [5–7].

Several recent studies have reported that negative psychological and physiological implications of stress disorder can lead to sleep disturbances [8–10], which in turn can manifest in poor quality of sleep and other health risks including death [11]. Coincidentally, sleep disorder corroborates with increased level of anxiety [12]. The positive effects of manual massage on sleep and anxiety disorder has been documented for different clinical groups in several studies. In one long term study involving pregnant women, researchers found that full body manual massage significantly decreased salivary cortisol and increased immunoglobulin production, thus decreasing stress and boosting immunity [17]. Similarly, foot and back massage improved blood

*Author to whom correspondence should be addressed.

pressure (BP) and sleep quality in hypertensive women [19]. Moreover, patients from critical care, colorectal surgery, and burn units also exhibited lower levels of anxiety and better perception of sleep when their treatments were supplemented with Swedish and aromatherapy massage, respectively [13, 15, 20]. Apart from these, recent studies on healthy individuals also report that massage enhances sleep quality and autonomic function by lowering cortisol levels, BP, and pulse [14, 16, 18].

However, there remains multiple limitations in recent studies; and one such is limitation of measure. Most of the findings, especially those associated with sleep quality, have been developed on self-report measures. Furthermore, in some studies the synergistic effects of massage combined with some other therapy may have overshadowed the effects of massage alone. Moreover, due to the varied massage techniques utilized in these studies, it remains to be examined if the effectiveness of massage is associated with intensity of applied pressure on the body independent of technique. Some of these problems may be addressed through automated massage. In fact, automated massage is said to have added benefits over traditional massage: automated massage chairs always deliver consistent pressure irrespective of therapists' physical condition; the exact massage position and pressure can be precisely controlled considering an individual's body contour and physical condition; and it may be more beneficial to individuals who don't like being touched by strangers and are not prone to exhaustive exertion. Despite much technological advancement on measuring apparatus, the benefits incurred from automated massage modalities have not been well explored.

In essence, several earlier studies have shown that, in response to tactile stimulation through manually applied massage, blood flow within the different parts of the body is facilitated. Additionally, evaluation of alternative types of interventions such as pharmacological and complementary treatments, have been reported on their respective merits and limitations. However, to the best of our knowledge, there remains a dearth of information on the study of efficacy of automated electronic massage chair with regards to peripheral circulation and sleep quality. In these studies, we explore the effects of mechanically delivered massage on blood circulation and quality of sleep.

2. STUDY 1: INVESTIGATING EFFECTS OF OGAWA MASTER DRIVE AI AUTOMATED MASSAGE ON BLOOD CIRCULATION

2.1. Methodology

2.1.1. Participants

15 subjects (age 21.00 ± 2.00 years; height 165.51 ± 05.80 cm; weight 55.40 ± 7.35 kg; body mass index (BMI) 19.22 ± 2.23) meeting both the inclusion and exclusion criteria were recruited and completed the study. The study was approved by Universiti Malaya Research Ethics Committee under the reference no. UM.TNC2/UMREC-991. Inclusion criteria: (a) having a BMI of less than 28 kg/m^2, and (b) adult within the age group of 18–30 years. Exclusion criteria: (a) low tolerance to pain from massage induced pressure; (b) accustomed to smoking and consumption of alcohol; (c) has a history of cardiovascular disease, hormonal disease, skin disease, musculoskeletal disorders, depression and mental disorders; (d) suffering from chronic pain or operative or non-operative injuries such as chronic back or lower limb pain/injury; (e) on menstruation or pregnancy during the study period, as such conditions can account for unwanted changes in blood circulation. Before undergoing with the experiments, participants were informed of the complete study protocols and risks, and were asked for their consent.

2.1.2. Procedure

The study was designed a randomized controlled, cross-over, repeated measures, and single-blinded trial. Each participant had to partake in four different session spanning across four separate days. After a washout period of 24 hours, each individual would be crossed-over to the next session and consequently act as their own control for the entire study. Participants during massage session underwent a pre-programmed massage mode for 30 minutes, whereas during the control session, participants would only sit on the massage chair but receive no actual massage (Fig. 1). In both conditions, participants were asked to minimize their movements and refrain from falling asleep. 12 hours prior to each sessions, all the participants were requested to refrain from caffeinated beverages and ensure that they have due amount of sleep. During each visit, each participant were instructed to acclimatize to the massage chair by just sitting on it for 10 minutes. Afterwards, their blood pressures (BP) were recorded. Skin blood flow (SBF) was recorded for 5 minutes before and after each massage session, respectively. During measurement, participants were requested to refrain from making excessive body movements, falling asleep and talking. Also, an ambient temperature of approx. 25\celsius was maintained during the sessions.

2.2. Apparatus and Outcome Measurements

2.2.1. Massage Chair Configuration

The OGAWA Master Drive AI Massage Chair (Ogawa World Bhd.) was used for delivering massage to participants. Three pre-programmed massage modes used in the study—"blood circulation," "deep tissue," and "sweet dreams"—are combination of rolling, kneading and shiatsu techniques with varying levels of intensities. The massage positions and acupressure points, targeting various muscle groups, are predefined with reference to traditional Chinese massage techniques as seen in Figure 2; and mechanical tools embedded within the massage chair consisting of rollers, airbags and heaters function in a programmed fashion to deliver the different types of massage.

2.2.2. Blood Pressure

At the end of the acclimatization period, a measurement of the subject's blood pressure (BP) was taken to ascertain whether their BP had normalized-less than 120/80 mmHg. The BP was measured at the heart level on the non-dominant forearm as the subject relaxed in a supine position. The measures were run thrice and only the mean value of the BP was recorded. The

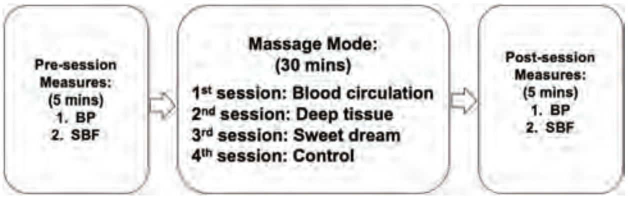

Fig. 1. Schematic diagram outlining experimental protocol.

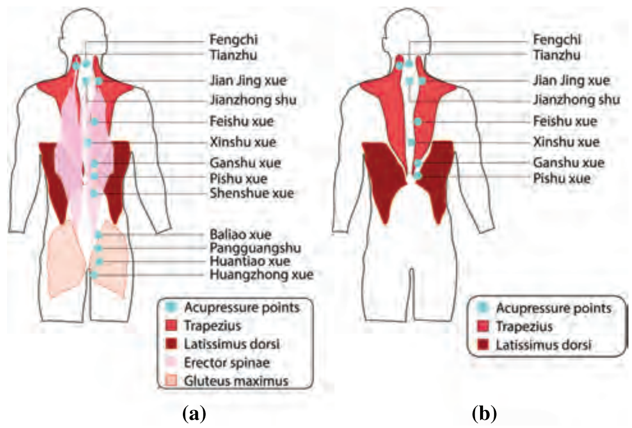

Fig. 2. Acupressure points and associated muscle group targeted by the massage modes—(a) blood circulation and deep tissue, (b) sweet dreams.

blood pressure (BP) was measured with a Colin Press Mate BP 8800P NIBP Blood Pressure Monitor (Colin Europe, Courbevoie, France).

2.2.3. Skin Blood Flow

The skin blood flow (SBF) was measured with a single-point laser Doppler flow meter (Periflux System 5000, Perimed, Järfälla, Sweden) in arbitrary perfusion unit (PU). A single probe was placed on the volar surface of non-dominant forearm at the antecubital fossa region with the upper limb relaxed and placed in a slight abduction, and forearm supination shown in Figure 3. The site of measurement was cleaned by first using an adhesive tape to remove the superficial dead layer of the skin, and then with alcohol pad before attaching the probe. The SBF measurement was recorded on the same marked site before and immediately after the massage/control session, for a period of 5 minutes. The mean value of SBF was used for the statistical analysis.

2.2.4. Data Analysis

The statistical analysis was performed with the IBM-SPSS software (version 25.0, SPSS Inc., Chicago IL, USA). The outcome measures were calculated and presented as mean and standard deviation. The intrasession repeatability for measurements was evaluated by the intraclass correlation coefficient (ICC) and the coefficient of variation (CV). The ICC was calculated using the one-way random model with their 95% confidence intervals and

Fig. 3. A laser doppler flowmeter (LDF) is used to measure the SBF by positioning the LDF meter probe on the antecubital fossa region.

Table I. Intrasession repeatability outcomes for the SBF measurements in the four sessions.

	Control		Blood circulation		Deep tissue		Sweet dreams	
Parameters	Pre	Post	Pre	Post	Pre	Post	Pre	Post
ICC	1.00	1.00	0.99	0.96	0.99	0.87	1.00	0.96
CV (%)	1.94	2.27	2.77	5.51	2.97	8.60	2.61	5.63

Notes: Data presented are mean; ICC: intraclass correlation coefficient; CV: coefficient of variation.

used to assess the relative homogeneity between the repeated measurements within single massage session [22]. The higher the ICC value is, the greater intrasession repeatability it represents within repeated measurements meaning there is no variance and the ICC value will achieve 1.0 [35]. As for the CV, it was calculated using the within-subject standard deviation method; that is, within-subject standard deviation per overall mean multiplied by 100 [23]. Smaller CV value represents smaller intrasession variation and greater intrasession repeatability [21]. The Shapiro-Wilk test was used to test for normality of measured variables. As the measured variables were found not normally distributed, therefore Wilcoxon signed rank test was used to assess the intersession differences between pre- and post-sessions. Furthermore, the intersession repeatability between the massage modes in the pre-session as well as the intersession difference between pre- and post-session were also assessed by Bland-Altman analysis. Finally, the intersession difference between any two of the four sessions was assessed by ANOVA, where $p < 0.05$ was considered as statistically significant.

2.2.5. Results

Table I shows the intrasession repeatability outcomes for the SBF in both pre- and post-session in each of the four massage modes. The ICC values in all massage modes are larger than 0.90 (0.96 to 1.00); thus, the intrasession repeatability is considered as high except for deep tissue post session (0.87). The CV values in all massage modes ranged from 1.94 to 8.60%, with deep tissue post session yielding highest variability (8.60%). Table II shows the intersession repeatability outcomes for the SBF measurements during the pre-session in control and three massage modes. The mean differences (Md) ranged from 0.92 to 4.11. Additionally, there is a significant increase in SBF from the pre-session to the post-session ($p < 0.05$) in all massage modes except for control mode, which shows no significant difference between pre-session and post-session ($p > 0.05$) as presented in Table III. Similarly, in the Bland-Altman plots of intersession measurements, the highest concordance—with lowest biases and narrowest limits of agreement—is found for SBF measured in control pre-session compared to post-session (Md 0.4876, 95% CI −0.5417 to 1.5168 PU) shown in Figure 4.

However, the SBF readings in the post-session exceeded the mean pre-session in blood circulation, deep tissue and sweet dreams modes with a Md of 6.0676 (95% CI −1.4544 to 13.5895) PU, 10.2301 (95% CI −0.6938 to 21.154) PU and 6.5123 (95% CI 0.7476 to 12.2771) PU shown in Figure 5–7, respectively. Furthermore, ANOVA post hoc analysis presented in Table IV shows that there is significant increase in SBF between pre-and post-session in blood circulation, deep tissue and sweet dreams modes, respectively ($p > 0.05$) in contrast to the control mode ($p < 0.05$). The significant increase of SBF between

Table II. Intersession repeatability outcomes for the SBF measurements in the pre-session in control and three massage modes.

Parameters	C and BC	C and DT	C and SD	BC and DT	BC and SD	DT and SD
Md	0.92	2.13	2.80	2.50	3.03	4.11
95% CI	3.02 to −1.19	10.48 to −6.21	11.32 to −5.72	10.32 to −5.31	11.98 to −5.92	15.33 to −7.10

Notes: Data presented are mean; C: control; BC: blood circulation; DT: deep tissue; SD: sweet dreams; Md: mean difference; 95% CI: 95% confidence intervals.

Table III. Comparison of SBF measurements before and after the four sessions.

	Pre-session	Post-session
Control	13.25 ± 4.20	13.74 ± 4.21
Blood circulation	13.66 ± 4.26	19.73 ± 6.87*
Deep tissue	13.18 ± 4.28	23.41 ± 6.78*
Sweet dreams	14.05 ± 5.60	20.57 ± 6.88*

Notes: Data presented are mean ± SD; Unit: SBF (PU); *Significant difference at p-value <0.05.

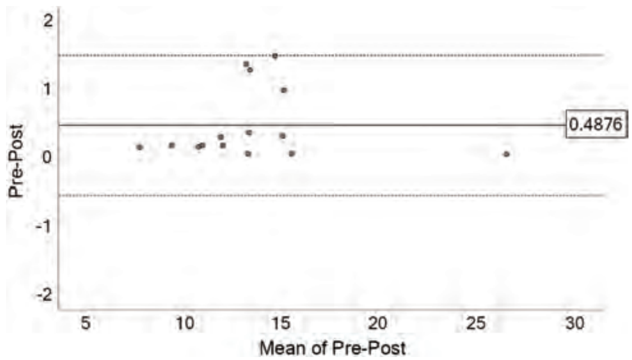

Fig. 4. Bland-altman plot of SBF measurements (unit: PU) between the pre- and post-session in control mode.

pre- and post-session in deep tissue mode was higher than that of the blood circulation and sweet dreams modes, respectively ($p < 0.05$); however, there is no significant difference between the increase of SBF between pre- and post-session in blood circulation and sweat dreams modes ($p > 0.05$).

3. STUDY 2: INVESTIGATING EFFECTS OF OGAWA MASTER DRIVE AI AUTOMATED MASSAGE ON SLEEP QUALITY

3.1. Methodology

3.1.1. Participants

5 males (age 24.00 ± 3.00 years; weight 73.10 ± 5.63 kg; height 178.28 ± 10.08 cm; body mass index (BMI) 22.49 ± 1.89) were recruited for the experimental procedures. Percipient selection was made based on the similar set of inclusion-exclusion criteria stated in study 1. The study was approved by Universiti Malaya Research Ethics Committee under the reference no. UM.TNC2/UMREC-991.

3.1.2. Procedure

Initially, the recruited participants were instructed on the experimental protocol, and before commencing experiments, their informed consents were obtained. Afterwards, participants underwent a single massage session every day for three consecutive days. Each participant wore an Actigraph GT9X Link on their non-dominant wrist 24 hours after massage session for the duration of the entire study period, to monitor their sleep pattern. The Actigraph was taken off only during massage session, and bathing to avoid damage from water. The compliance for wearing the GT9X Link was set to minimum of 18 hours/day. The participants had to complete a questionnaire twice: at the beginning, and at the end of their three-day massage period. During the study period, participants were asked not to take antidepressants and caffeinated drinks.

3.2. Apparatus and Outcome Measurements

3.2.1. Massage Chair Configuration

For the purpose of this experimental study, a pre-programmed massage mode—"Sweet Dreams" was used. Participants were asked to remove any bracelets, watches, or sharp objects for safety reasons.

3.2.2. Wrist Actigraph

In this study, Actigraph GT9X Link was used to objectively determine the quality of sleep. The Actigraph is a small wrist-worn device that continuously monitors human activity or movement. Researchers have stated that periods of movement suggest wakefulness whereas those of relative stillness likely correspond to sleep or quiescence [31]. The device had been reported to be at 91% and 85% in agreement with polysomnography (PSG) in terms of sensitivity and accuracy, respectively [32]. Additionally, due to its small size and mobility of use, the Actigraph GT9X was better suited to the needs of this study. Data collected via Actigraph device was processed and analyzed with its companion software CentrePoint.

3.2.3. Questionnaires

Participants were asked to fill out a questionnaire: Richard Campbell Sleep Questionnaire (RCSQ). The RCSQ consisted of five items with each item on the questionnaire set to a 0–100 mm

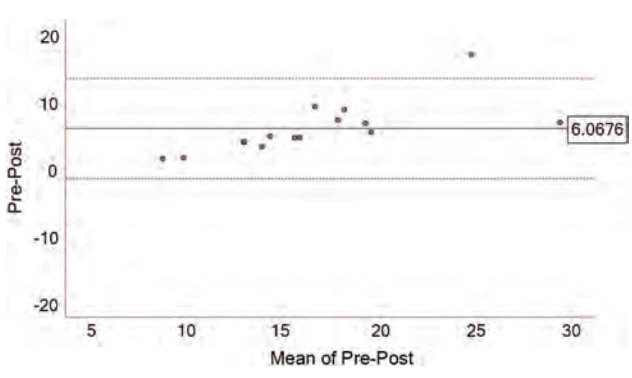

Fig. 5. Bland-altman plot of SBF measurements (unit: PU) between the pre- and post-session in blood circulation mode.

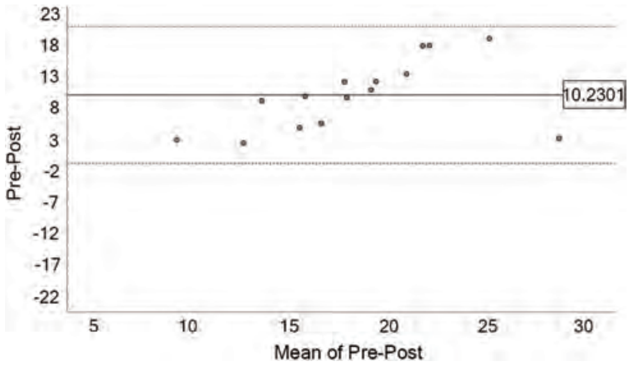

Fig. 6. Bland-altman plot of SBF measurements (unit: PU) between the pre- and post-session in deep tissue mode.

visual analogue scale. In order to acquire the total score, the derived values were initially added and subsequently divided by five. The results reflect the patient's perception of sleep quality. In a psychometric evaluation of the RCSQ, researchers found an internal consistency of 0.90 and demonstrated that scores on the scale have a correlation of 0.58 with the same sleep variables as measured by PSG [34].

3.2.4. Results

Table V shows the sleep parameters monitored by the Actigraph before and after the 3 days of consecutive massage sessions. Among these parameters are (i) duration of sleep, (ii) average awakening which indicates the mean time the subject was awake during his sleep duration, (iii) sleep onset latency, (iv) total time awake, (v) time asleep which is the total time asleep during the recording which is distributed among non-rapid eye movement and rapid eye movement stages, (vi) number of awakening, (vii) total epoch counts, and (viii) efficiency.

From the results, it is observed that subject 1 exhibits minor improvements in terms of average awaking time as captured by the fewer awakening events after receiving massage. However, despite subject 1's improvement, there duration of sleep over the session receded as evidenced by the data. In contrast, subject 2's duration of sleep diminished over the study period despite surprisingly improved awakening counts and sleep efficiency. As for subject 3, there appears to be no alteration in the duration of sleep between pre- and post-massage sessions; therefore, viewing

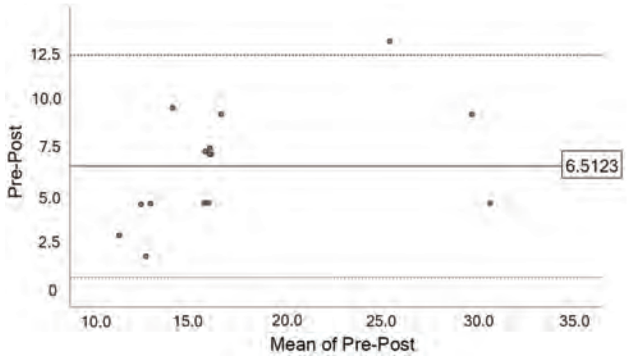

Fig. 7. Bland-altman plot of SBF measurements (unit: PU) between the pre- and post-session in sweet dreams mode.

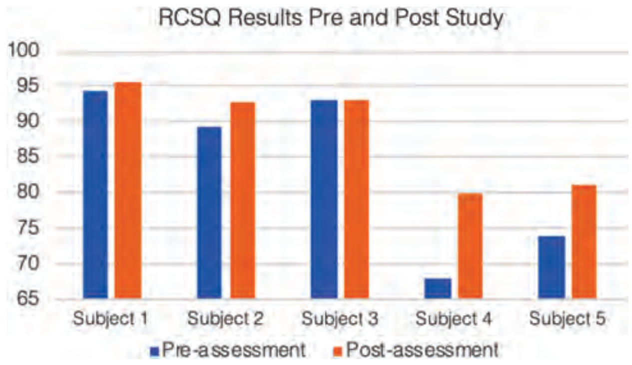

Fig. 8. Total score of each subject as measured from RCSQ before and after massage sessions.

Table IV. Comparison of percent-change in SBF before and after the four sessions.

	Control	Blood circulation	Deep tissue	Sweet dreams
Pre-post percentage change (%)	3.81 ± 3.91	43.48 ± 23.34*	81.32 ± 41.86*	49.60 ± 23.57*

Notes: Data presented are mean ± SD; *Significant difference at p-value <0.05 versus control.

other sleep indicators, it is noticeable that after taking the massage sessions, subject 3 exhibits a better sleep efficiency as well as fewer awakenings. Like subject 2, it is observed that subject 4 has shorter duration of sleep. Again, for subject 5, comparison of pre-and post-session results a relatively short sleep duration. The number of awakenings does not change for subject 5 before and after massage.

4. DISCUSSION

The first study evaluates the intrasession repeatability of SBF measurement in pre-and post-session in each massage mode by using a single-point laser Doppler flow meter. In general, an ICC value is above 0.75 suggests good intrasession repeatability; however, most clinical applications require a higher ICC value (0.90) [24]. In our study, most of the ICC values of SBF parameters are above 0.90 except for deep tissue post session (0.87), suggesting moderate intrasession repeatability of SBF measurements [36]. The CV values of all the parameters ranges from 1.94 to 5.63% except for deep tissue post session (8.60%), which also suggests small intrasession variations of the consecutive measurements [23]. The moderate intrasession repeatability indicated by the deep tissue post session may be attributed to the limited reproducibility, because the SBF measurement is restricted to the minute area in contact with an optical fiber [25]. Probably due to the movement artefact, to which laser Doppler flowmetry is sensitive, the movement of the optical in connection with the probe and the movement of the poorly compliant subjects may produce anomalies during the measurement [26].

Indeed, the ICC and CV values confirms the single-point laser Doppler flow meter may have had a high intrasession repeatability for the SBF measurements. The mean differences (Md) ranging from 0.92 to 4.11 shown in the intersession repeatability outcomes for the SBF measurements in the pre-session in control

Table V. Sleep parameters measured through Actigraph at the beginning and at the end of 3 consecutive massage sessions.

	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5	
	Pre-session	Post-session	Pre-session	Post-session	Pre-session	Post-session	Pre-session	Post-session	Pre-session	Post-session
Time in bed (minutes)	492	406	226	375	407	399	268	231	272	204
Average awakening (minutes)	2.86	2.09	2.35	3.73	2.31	2.68	3.64	3.00	3.00	1.92
Time awake (minutes)	83	46	40	56	67	59	80	36	39	23
Time asleep (minutes)	409	360	186	319	340	340	188	195	233	181
Awakening count	29	22	17	15	29	22	22	12	13	12
Total counts	36,680	21,601	14,384	25,679	29,909	22,245	37,113	14,868	25,028	10,785
% efficiency	83.13%	88.67%	82.30%	85.07%	83.54%	85.21%	70.15%	84.42%	85.66%	88.73%

and three massage modes indicates a limitation in spatial resolution, where there may be a discrepancy in blood flow responses in the same skin site on the same individual [27]. As far as it is concerned, the present study first to narrate SBF measurement for the automated massage. The SBF is significantly elevated with each massage session in contrast to the control session. In the Bland-Altman analysis, there is a significant difference found in SBF between the pre- and post-session when comparing mean values between sessions; however, the mean difference between pre- and post-session in control mode is close to zero and the range of the 95% CI is narrow, suggesting no significant difference in SBF mean values between the pre- and post-session.

The increase in SBF may be related to the mechanical stimulation which was produced by the massage involving mechanical pressure on soft tissues [28]. Moreover, the possible reason for the increased SBF response could be due to the frictional effects from massage, which may cause increased skin temperature that activates the thermoregulatory reflexes to inhibit vasoconstrictor outflow leading to passive vasodilation of the cutaneous circulation [29]. Meanwhile, it also promotes the active vasodilator system which in turn will bring about an increase in skin blood for the heat dissipation [30]. The subjects have reported feeling a warm sensation being felt in the limbs and lower back during the post massage session. In comparison, the significant increase in SBF between pre- and post-session in deep tissue mode is higher than of the blood circulation and sweet dreams modes respectively. It is also observed that the deep tissue massage has been applied on the latissimus dorsi more consistently, and each massage transition takes a longer time compared to the blood circulation and sweet dreams modes. Besides, the massage on the latissimus dorsi is known to improve edema by promoting blood circulation within the muscle [31]. Multiple subjects have reported feeling much more pressure applied during deep tissue massage which is believed to increase cutaneous vasodilation by encouraging the release of the neurotransmitter histamine through deep strokes during deep tissue massage more effectively [32].

The results of the current study shed light on the effects of automated massage in the blood circulation. However, the studies can be further improved with sample size comprises of adults from all range age groups. Moreover, the measurement for SBF was restricted to a relatively small area by a single-point laser doppler fiber-optic probe, which may have caused decreased spatial resolution. Another limitation related to the reduced spatial resolution is the sensitivity of probe towards the movement of fiber cable or subject. The immediate effect of automated massage on the blood circulation measured in the current study does not elucidate the long-term effects of using the automated massage chair. In the future studies, larger sample size should be employed to evaluate the robustness of SBF measurement to adapt to the variability in blood flow responses between individuals. To counter the limitation in spatial resolution, integrated multi-point laser Doppler probes that increase the volume of tissue under the probe in order to reduce site-to-site variability can be used. In addition, a vacuum cushion around the experimental limb or other isolation method may be used to reduce movement artefact from the fiber cable or the subject. To add more impact for the clinical benefit, we suggest measuring the duration of the automated massage effect on the blood flow. Because the current study measured SBF on the dermal surface layer, further studies can be employed to measure the blood flow in deep arteries after the automated massage therapy.

5. CONCLUSION

The effect of Ogawa Master Drive AI automated chair massage on blood circulation and sleep quality was examined in these two explorative studies. In the first study, the single-point laser Doppler flow meter was used and found to have a high intrasession repeatability for the SBF measurements. A significant increase in mean SBF from the pre-session to the post-session in all massage modes except for control mode was observed reflecting possible improvement in the cutaneous blood circulation. The study also found that the significant increase in SBF between pre- and post-session in deep tissue mode was higher than of the blood circulation and sweet dreams modes respectively, suggesting that increased moderate intensity is more effective to increase blood flow than light intensity massage. As for the second study, sleep efficiency in participants improved. Future studies should investigate the longitudinal effects of automated massage on sleep quality with larger population.

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