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Original Article

Optimization of Tuina rolling manipulation parameters to promote blood circulation using a circulatory orthogonal experiment

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Abstract. [Purpose] To determine the optimal Tuina rolling manipulation parameters for improving peripheral blood circulation and to observe the duration of these effects. [Participants and Methods] A total of 162 healthy males and 20 males with coronary heart disease were recruited, with a mean age of 29.5 ± 6.4 years. The change in blood flow was used as the observation index, and the best combination of parameters was selected using a cyclic orthogonal experiment. We observed changes in rolling manipulation across different time periods and groups. [Results] There were significant interactions between pressure, frequency and duration in the rolling manipulation. The combination mode of 4 kg, 120 repetitions/min and 10 min is the most effective to improve the average blood flow increase rate of popliteal artery. At 15 minutes after manipulation, different degrees of significant increase were observed, but 20 minutes after manipulation, the average blood flow rate returned to the premanipulation level. There was no difference in blood flow rate between healthy males and coronary heart disease patients. [Conclusion] An effective dynamic model of rolling manipulation was constructed. These results contradicted the idea that more pressure and longer continuous manipulation led to stronger effects. The effect of rolling manipulation on improving peripheral circulation can be maintained for 20 minutes.

Key words: Chinese massage, Dynamic parameters, Hemodynamic indices

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INTRODUCTION

Tuina, a Chinese therapeutic method, has a history over thousands of years and is widely used in Chinese rehabilitation belonging to the category of manipulative therapy. Tuina has unique effects on musculoskeletal disorders, neuropsychiatric disorders, cardiovascular disorders and many other diseases[1, 2)]. Numerous experiments have demonstrated the unique advantages of Tuina in treating disorders of the musculoskeletal system[3, 4)]. Tuina acts as a mechanical stimulator that can alleviate pain, regulate the satellite cells of skeletal muscles, and influence immune responses, thereby contributing to muscle injury recovery[5, 6)]. In addition, Tuina manipulation is a painless, nontoxic, noninvasive natural treatment that is well known among patients[7)]. Rolling manipulation, which is one of the most influential contemporary Tuina techniques, is a myofascial release technique with moderate strength and significant efficacy[8)].

The curative effect of rolling manipulation is determined by the stimulation quantity, which consists of the pressure, frequency and duration of manipulation[9)]. The pressure of manipulation is the key factor in determining the stimulation

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quantity[10]. However, the results of clinical experience with Tuina show that a greater amount of pressure does not yield a better effect[11]. The frequency of rolling is another important factor affecting the amount of stimulation[12]. In the process of rolling manipulation, when the frequency is fast, the pressure generated is small, and when the frequency is slow, the pressure generated is large, and different frequencies have different effects on the disease[13, 14]. Duration is the third factor in the quantity of stimulation. The duration of rolling manipulation should be increased or decreased based on the severity of the disease[15]. A rolling manipulation duration that is too long is not conducive to recovery from the disease and may even aggravate the disease[16]. Pressure, frequency and duration all have an impact on the quantity of stimulation, and the three factors influence and cooperate with each other[17]. Therefore, purposeful changes in the pressure, frequency and duration of manipulation will alter the quantity of stimulation accordingly[18]. Differences in the operator's understanding of the theory of Tuina manipulation and differences in manipulation techniques further lead to differences in the quantity of stimulation, thus affecting the effectiveness of disease treatment[19]. Therefore, optimizing the pressure, frequency, and duration of rolling manipulation and standardizing the operator's actions are critical to achieve the maximum therapeutic effect.

Recent studies have shown that Tuina can cause peripheral vasodilatation, increase the oxygen demand of local tissues, and activate blood circulation by improving the hemodynamics of the lesion site, thereby promoting disease repair[20, 21]. However, the dynamic trend of the hemodynamic changes in the Tuina needs to be further studied, and there are no exact data indicating how long the hemodynamic changes in the Tuina can be maintained[22, 23]; therefore, there are no exact data showing how long the therapeutic effect of Tuina can be maintained.

This study comprises two parts. Experiment 1 focused on exploring the dose–effect relationships among pressure, frequency, and duration and determining the optimal combination of parameters. Experiment 2 focused on the effect of the optimal combination of parameters for rolling manipulation on the duration of hemodynamic changes. The duration of clinical efficacy of Tuina was further explored. Our results provide insights into the clinical prescription of Tuina.

PARTICIPANTS AND METHODS

In Experiment 1, 162 healthy male participants were recruited for this study. Each round of orthogonal experimental screening was repeated twice according to the orthogonal table L_{27} (3^{13}), resulting in a total of three rounds with 54 cases per round, yielding a sample size of 162, which not only increased the amount of information in the sample but also allowed for analysis of variance to satisfy the purpose of the test. In Experiment 2, 20 male patients with coronary heart disease and 20 healthy male participants were enrolled. The participants' mean age (29.5 ± 6.4 years), lower limb disability, muscular dystrophy, and psychiatric disorders were excluded, and they all volunteered to participate in the study and signed an informed consent form. The inclusion criteria for the coronary heart disease group were patients who met both the Western[24] and Chinese[25] diagnostic criteria and who had a history of sudden onset chest tightness and/or pain and symptoms such as chest pain, chest tightness, chest congestion, palpitations, purple lips and tongue, and astringent pulse. The included participants were in stable condition and able to lie prone for 30 min.

Experiment 1: Three orthogonal tests were conducted in this study. Based on the parameters of the commonly used clinical rolling manipulation, the initial levels of pressure for the first round of tests were 2, 4, and 6 kg; the initial frequencies were 60, 120, and 180 repetitions/min; and the initial durations were 5, 10, and 15 min. The second round of testing used the most effective parameter from the first round of orthogonal testing as the base parameter. The fluctuation parameter was the 1/2 level of the parameter difference in the earlier experiment; the screening range was reduced; the factor and level parameters of the experiment were selected; and the orthogonal test optimization screening was repeated. Next, the screening range was gradually narrowed to a certain range, with the termination point being that there was no significant difference in the effect of parameter matching on hemodynamics. Computer-generated random numbers were used to ensure hidden participant assignment, maximize the repeatability of the procedure, and increase comparability between groups. L_{27} (3^{13}) was selected for the orthogonal table. The design factors and levels of the orthogonal test are shown in Table 1. Experiment 2: The optimal combination of parameters screened in Experiment 1 was applied to 20 male participants with coronary heart disease and 20 healthy males. Changes in popliteal artery blood flow were observed before the rolling manipulation, immediately after the rolling manipulation, and at 5 min, 10 min, 15 min, and 20 min after the rolling manipulation.

In the intervention method of Experiments 1 and 2, the rolling manipulation was carried out in accordance with the following key points[26]. The back of the palm of the hand near the little finger was pressed against the treatment area with

Table 1. Factors and levels in the orthogonal test design

	First round			Second round			Third round		
	Pressure (kg)	Frequency (repetitions/min)	Duration (min)	Pressure (kg)	Frequency (repetitions/min)	Duration (min)	Pressure (kg)	Frequency (repetitions/min)	Duration (min)
Level 1	2	60	5	3	90	7.5	3.5	105	8.75
Level 2	4	120	10	4	120	10	4	120	10
Level 3	6	180	15	5	150	12.5	4.5	135	11.25

the metacarpophalangeal joint slightly flexed. A concerted movement of maximum wrist flexion and extension and forearm rotation was then performed, causing a continuous back and forth movement of the proximal little finger side of the dorsal part of the palm over the treatment area. The operator was trained repeatedly on the type II Tuina manipulation tester until it reached the standard of testing and evaluation of the rolling manipulation. The rolling manipulation site was chosen to be in the left lower limb gastrocnemius, and the intervention site was kept consistent across all participants to avoid variability in the experimental data. The participants were in a prone position, and the lower part of the left leg was placed on the force-measuring table of a type II Tuina manipulation tester. The pressure, frequency and duration of the procedure were selected according to an orthogonal table, and the gastrocnemius muscle of the left lower limb was manipulated by rolling manipulation. Moreover, the pressure, frequency and duration parameters of the manipulation were collected simultaneously by a type II Tuina manipulation tester and timer to verify the accuracy of the manipulation (Fig. 1, Appendix 1).

Ultrasonic testing: The patients laid prone on the treatment bed, exposing the left lower limb above the popliteal fossa. The ultrasonographer applied a coupling agent to the probe and probed the popliteal artery in the participant's left lower limb at an angle of 50–60° and a depth of 4.0–5.0 cm. The diameter, area, mean flow velocity and blood flow of the popliteal artery were detected by a color ultrasonic Doppler diagnostic system (SonoScape, Shenzhen, China) until the blood flow in the popliteal artery returned to its pretreatment state (Fig. 2). All the measurements were performed by the same associate chief physician, and the direction and depth of the probe were kept consistent during the measurements.

Experiment 1: At the end of each test, the ultrasonic examination images and text reports before and after the manipulation were given to the statistician, who sorted the hemodynamic indices in the image according to the corresponding number and statistically assessed the results after each round of testing. The statistical results were given to the designer, and according to the statistical results, the designer reduced the screening scope, formulated the factor level value of the next round of the orthogonal test, and specified the test sequence according to orthogonal table L_{27} (3^{13}). Experiment 2: At the end of the trial, the blood flow values for each period were accurately recorded on the clinical observation table; the ultrasonic examination

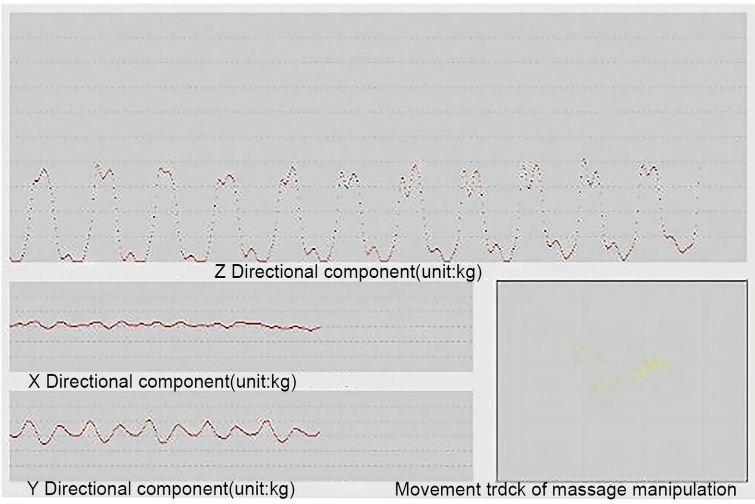

Fig. 1. The rolling manipulation curve diagram collected by the type II Tuina manipulation tester.

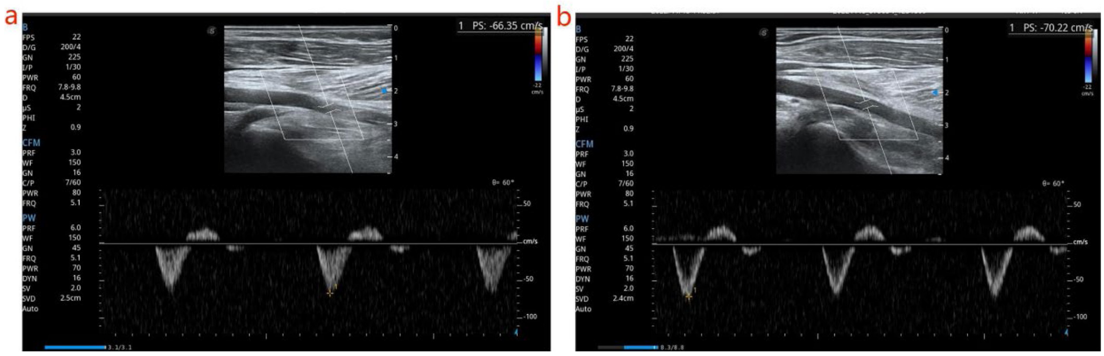

Fig. 2. Hemodynamic results of the popliteal artery were detected by B-ultrasound. (a) The results prior to the rolling manipulation are displayed. (b) Changes in blood flow after rolling manipulation.

images and text reports before and after the operation were pasted onto the case report table; the hemodynamic test results were input into the predesigned computer database; and the data were managed and maintained.

The data collection site for both Experiment 1 and Experiment 2 was the hospital B-ultrasound room from 15:00 to 17:00 pm. The following parameters were examined: popliteal artery diameter, area, mean flow rate and mean blood flow. Blood flow was the main test parameter. The mean blood flow (volume flow, VF) in the popliteal artery was measured via color Doppler ultrasound to quantitatively, dynamically and continuously measure and analyze the blood movement pattern. The rate of average blood flow increase was calculated as follows:

$$\text{Rate of average blood flow increase}=(VF_{after}-VF_{before})/VF_{before}\times 100\%$$

The blood flow data were analyzed using SPSS 25.0 for Windows statistical software, and $p<0.05$ indicated statistically significant differences. The orthogonal test used ANOVA to analyze the main effects and interactions of the factors. Non-normally distributed data were analyzed using the Wilcoxon signed-rank test. The experimental results are expressed as the mean ± SD.

This study was approved by the Ethics Committee of Yueyang Hospital of Integrated Traditional Chinese and Western Medicine affiliated with Shanghai University of Traditional Chinese Medicine (Approval number: 2018-123). This experiment was registered with the Chinese Clinical Trial Registry (ChiCTR1900021230).

RESULTS

Experiment 1: Optimizing the Parameters of Rolling Manipulation. The parameters for the orthogonal optimization screening method were determined based on clinical application and the body's tolerance. The pressure was set at 2, 4, and 6 kg, the frequency was set at 60, 120, and 180 repetitions per minute, and the duration was set at 5, 10, and 15 minutes. According to the principle of orthogonal optimization screening, there were interactions among the test factors. The most significant effect of the interaction was the best combination. The best combination selected from the first round of orthogonal optimization screening tests of normal dynamic parameters was the combination of pressure of 4 kg, frequency of 120 repetitions/min and duration of 10 min (Table 2). The results showed that the main effects of rolling manipulation pressure, frequency and duration were significant for blood flow ($p<0.05$). There were still significant interactions between any two factors and between all three factors ($p<0.05$). Thus, the optimal combination of the three parameters was determined by the interaction effects of the factors. Nonetheless, the statistical analysis indicated significant differences in the main effects and interactions of diverse factors, requiring further narrowing of the scope for cyclic orthogonal screening.

The second round of orthogonal optimization screening showed that a pressure of 4 kg, a frequency of 120 repetitions/min, and a duration of 10 min was the most effective combination of parameters to improve blood flow in the popliteal artery (Table 3), despite variations in frequency (90, 120, 150 repetitions/min), duration (7.5, 10, 12.5 min), and pressure (3, 4, 5 kg). There were no significant differences in the main effects of pressure or duration in the second round of the experiment ($p>0.05$). However, a significant difference was observed between the main effects of different frequencies ($p<0.01$). As a result, increasing the pressure and duration of treatment does not enhance the therapeutic effect of rolling manipulation. However, there were significant interactions among the three factors of pressure, frequency, and duration, whether between two or among three factors, based on the analysis of the interaction effect ($p<0.05$). The process of rolling manipulation was characterized by the interdependence and interaction of its parameters. When any one factor was altered, it affected the overall outcome. Consequently, the optimal combination of the three parameters was selected based on their interaction effect rather than the main impact of a single factor. Since there were dissimilarities in the primary effects of the various frequency factors, further narrowing of the scope was necessary for optimization and screening.

Table 2. Effects of different parameters in the first round on the rate of increase in average popliteal-artery blood flow

Pressure	Frequency	Duration (min)		
(kg)	(cpm)	5	10	15
2	60	31.05 ± 22.47	21.36 ± 18.49	45.31 ± 21.43
	120	77.72 ± 20.50	60.21 ± 18.34	65.73 ± 19.56
	180	51.60 ± 21.45	82.43 ± 21.77	59.28 ± 14.21
4	60	48.91 ± 19.40	50.32 ± 14.21	84.66 ± 30.22
	120	66.84 ± 18.68	95.00 ± 31.77	68.20 ± 18.34
	180	60.76 ± 15.89	61.20 ± 25.87	46. 17 ± 22.47
6	60	35.61 ± 20.46	21.69 ± 15.98	34.68 ± 14.21
	120	65.82 ± 15.89	39.88 ± 15.24	50.69 ± 16.87
	180	63.76 ± 25.49	21.94 ± 15.89	47. 16 ± 20.47

The third round of orthogonal optimization screening revealed no significant differences in the main effect or interaction effect of the three factors on blood flow changes when the pressure ranged from 3.5–4.5 kg, the frequency ranged from 105–135 repetitions/min, and the duration ranged from 8.75–11.25 min. There were no significant interactions observed between all three factors or between any combination of two factors. After conducting three rounds of the experiment, we found that the horizontal values of the three factors were narrowed to the minimum range. Based on three rounds of cyclic orthogonal screening, we concluded that the optimal combination of parameters for promoting peripheral circulation through rolling manipulation was as follows: pressure of 4 kg, a frequency of 120 repetitions/min, and a duration of 10 minutes.

Experiment 2: Observation of the effective duration of rolling manipulation in promoting peripheral circulation. The study results showed that the popliteal blood flow increased to different degrees in both groups immediately after the rolling manipulation and at 5 min, 10 min, and 15 min after the manipulation ($p<0.05$). However, 20 minutes after the rolling manipulation, the popliteal blood flow rate returned to the premanipulation level (Table 4). Compared with the premanipulation blood flow rates, there were significant differences at all observation points except at 20 minutes ($p<0.05$). In addition, there was no difference in the corresponding observation points between the healthy group and the coronary heart disease group ($p>0.05$).

DISCUSSION

Experiment 1: Optimizing the parameters of rolling manipulation. Rolling manipulation is a noninvasive therapy characterized by the application of body manipulation to stimulate mechanical force, and this mechanical force stimulation can be transformed into a biological effect in the body, thus achieving appropriate disease treatment. Appropriate mechanical force stimulation can promote tissue cell growth, differentiation, and maintenance, while excessive or long-lasting mechanical force stimulation can cause tissue cell damage and easily cause adverse reactions such as skin damage, subcutaneous blood stasis and even syncope[27, 28]. Long-term clinical practice suggests that the effectiveness of manipulation treatment depends on the amount of stimulation received[29]. The amount of rolling stimulation is determined by the pressure, frequency, and duration of the rolling manipulation parameters. Altering any of these elements will also differ the amount of stimulation, leading to therapeutic effects with distinct characteristics[30].

The results of the present study revealed that the combination of parameters at any level improved the rate of increase in VF. However, a pressure of 4 kg, a frequency of 120 repetitions/min and a duration of 10 minutes improved the VF increase rate most significantly and produced the strongest effect on promoting peripheral circulation. The experimental results revealed no positive correlation between the therapeutic effect of rolling manipulation and the magnitude of the horizontal values of pressure, frequency, or duration parameters. Additionally, it is suggested that the clinical application of

Table 3. Effects of different parameters in the second round on the rate of increase in average popliteal-artery blood flow

Pressure	Frequency	Duration (min)		
(kg)	(cpm)	7.5	10	12.5
3	90	38.93 ± 12.81	33.69 ± 13.56	46.34 ± 12.84
	120	23.51 ± 10.71	50.87 ± 12.65	40.46 ± 12.66
	150	43.99 ± 11.92	28.57 ± 10.73	23.39 ± 10.82
4	90	28.47 ± 10.78	51.80 ± 12.56	46.36 ± 13.54
	120	31.05 ± 12.35	87.51 ± 25.21	46.26 ± 10.53
	150	30.02 ± 12.73	38.61 ± 15.31	33.01 ± 12.79
5	90	72.89 ± 11.68	49.95 ± 13.44	60.55 ± 19.97
	120	43.09 ± 9.81	76.67 ± 12.62	30.47 ± 10.98
	150	60.94 ± 20.72	42.33 ± 10.68	53.13 ± 19.81

Table 4. Dynamic change in the rate of increase (%) in popliteal artery volume flow (VF) before and after the rolling manipulation

Dynamic observation point	Normal group	Patient group
Before the operation	0	0
Immediately after the operation	51.87 ± 8.54▲	56.98 ± 14.08▲
5 min	53.04 ± 7.58▲	56.83 ± 10.26▲
10 min	45.04 ± 8.48▲	55.28 ± 11.05▲
15 min	38.08 ± 9.88▲	50.10 ± 11.84▲
20 min	0.97 ± 2.22	0.04 ± 0.57

▲Compared with before the operation, $p<0.01$; there was no difference in the corresponding points between groups.

rolling manipulation is controlled by the pressure, frequency, and duration of parameters within a specific range. It is not wise to assume that increases in the pressure, frequency, or duration will always lead to better therapeutic outcomes.

Regarding the impact of manipulation pressure on nerve function, slight pressure inhibits central nerves and stimulates peripheral nerves, while strong pressure has the opposite effect[31)]. From the perspective of the human body's ability to withstand mechanical force stimulation, a moderate amount of stimulation is effective at stimulating receptors on the body's surface, resulting in a sense of comfort. However, the intensity of excessive stimulation can lead to further injury and diminish the treatment efficacy. Similarly, insufficient intensity cannot achieve the desired therapeutic effect. Thus, the strength of the rolling manipulation pressure should not be too strong or too weak. The experimental results revealed that optimal therapeutic efficacy is achieved with a rolling manipulation pressure of 3.5–4.5 kg. Notably, increasing the pressure level does not substantially enhance the therapeutic effect. It has also been shown that slow and slight stimulation suppresses sympathetic nerves and excites parasympathetic nerves, which has inhibitory and sedative effects[32)]; rapid and strong stimulation excites sympathetic nerves and suppresses parasympathetic nerves, which have excitatory effects[33)]. From the actual clinical observation, we can also see that the frequency of manipulation during treatment was not the fastest—instead, a medium frequency of manipulation was used. The results of this study also confirmed that the optimal therapeutic effect was achieved when rolling manipulation was performed at a moderate frequency of 105–135 repetitions/min, and a faster frequency did not improve the therapeutic effect. The best treatment effect can be achieved when the rolling manipulation duration is controlled within the range of 8.75 to 11.25 minutes. Prolonging the treatment duration is a waste of physical strength for the Tuina operator and is not in compliance with the principle of ergonomics.

The study employed the orthogonal experimental design method to analyze the commonly utilized parameters of clinical rolling manipulation. The screening process revealed a range of rolling manipulation parameters consisting of 3.5–4.5 kg of pressure, 105–135 repetitions/minute of frequency, and 8.75–11.25 minutes of duration, and the combination of 4 kg of pressure, 120 repetitions/minute of frequency, and 10 minutes of duration in this range most significantly improved popliteal artery blood flow. This suggests that the principle of "greater pressure, higher frequency, and longer duration equals better curative effect" is not valid.

Experiment 2: Observation of the effective duration of rolling manipulation in promoting peripheral circulation. When human skin is stimulated by rolling manipulation, the effective vasodilator SP in the skin is released from the nerve endings and activates nitric oxide synthase (NOS) in neighboring endothelial cells through the action of IκB kinase. NOS in turn synthesizes nitric oxide (NO), which leads to the expansion of dermal microvascular endothelial cells (DMECs), increases blood flow velocity and improves blood circulation[34, 35)].

In this study, the optimal combination of parameters screened for rolling manipulation, with a pressure of 4 kg, frequency of 120 repetitions/min and duration of 10 minutes, was applied to healthy participants and participants with coronary heart disease. Popliteal artery blood flow changes were measured before, immediately after, and at 5, 10, 15, and 20 minutes following the rolling manipulation. The results indicated a significant improvement in the rate of increase in popliteal artery blood flow in both healthy participants and those with coronary heart disease. VF reflects the change in blood flow per unit time and indirectly reflects the level of hemodynamics[22)]. This indicated that after being applied to the human body, rolling manipulation could increase the blood flow in the blood vessel per unit time and improve the hemodynamic level of the surrounding blood vessels to a certain extent to achieve the effect of promoting peripheral circulation[36)].

In this study, the rate of increase in popliteal-artery VF in both the healthy participants and participants with coronary heart disease increased rapidly immediately after rolling manipulation and then gradually returned to normal, indicating that rolling manipulation immediately promoted blood circulation that could be maintained for some time. The essence of rolling manipulation is a type of mechanical force[37)]. When a mechanical force is applied to the body surface, the body surface receptors convert mechanical stimulation into internal energy[38)]. By regulating the biological effects of the sarcoplasmic reaction and calcium ion flux and reducing the level of inflammatory factors, therapeutic aims can be achieved[39)]. When the stimulus stops, the biological effects gradually cease. Therefore, the therapeutic effect of rolling manipulation should gradually disappear by the end of manipulation. In this study, the rate of increase in VF in the two experimental groups peaked 5 min after rolling manipulation and returned to the premanipulation level within 20 min. The results showed that the effect of rolling manipulation on promoting blood circulation was immediate and nonpersistent, with a single rolling manipulation treatment lasting only 20 min, a result that could explain some of the clinical effects of Tuina. For example, patients feel that muscle pain is relieved immediately after Tuina because at that point, the muscles at the treatment site are relaxed, blood circulation is improved[40)], the absorption of edema and lesion products is accelerated, swelling spasm is eliminated, and the patient will naturally feel relieved, which is caused by the immediate effect of manipulation[5, 41)]. However, this therapeutic effect gradually disappears over time, and the pain returns after a short period[42)]. The pain can be completely relieved only after repeated sessions of Tuina, which has no persistent curative effect after one manipulation[43)].

The study results also showed that the rate of VF increase was slightly higher in participants with coronary heart disease than in healthy participants at each corresponding observation point. However, there was no significant difference between the two groups after a statistical comparison of the corresponding dynamic observation time points. The treatment effects that indicated the same stimulation quantity did not differ according to individual differences. This is because the pathways of mechanical force to human stimulation are basically the same, the rolling operation parameters implemented in both groups are the same, and all the other operating conditions are the same; therefore, the efficacy of the rolling manipulation on different individuals should also be basically the same.

In conclusion, Tuina is a precise technique that requires rigorous manual training and complete proficiency in optimally matching the amount of stimulation for optimal clinical outcomes[44, 45]. The present study identified the optimal combination of parameters for rolling manipulation, providing guidance and reference points for the standardization and normalization of clinical practice. Rolling manipulation promotes peripheral circulation by increasing hemodynamic levels and has both immediate and nonsustained effects. Immediate efficacy is reflected in the manipulation effect, which may occur and peak immediately after a rolling manipulation treatment. Nonpersistent effects indicate that the manipulation effect fades over time and lasts only 20 minutes.

This study has several limitations. In Experiment 1, only male participants were observed in the manual mechanics feature screening. However, we believe that there may also be differences in rolling manipulation adaptability among individuals of different sexes. Future research can be designed hierarchically according to sex and age to screen out the characteristics of manipulation suitable for different populations. The limitations of Experiment 2 include the relatively small and uniform sample size. The study involved only healthy participants and participants with coronary heart disease. Although the detection index was only used to observe changes in blood flow, it was difficult to achieve a double-blind random method during the intervention; this could have led to bias.

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Conflict of interest

There are no conflicts of interest related to this study to disclose.

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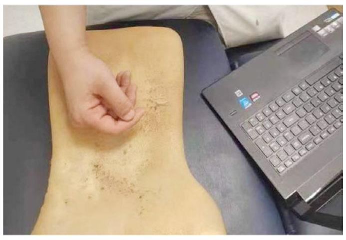
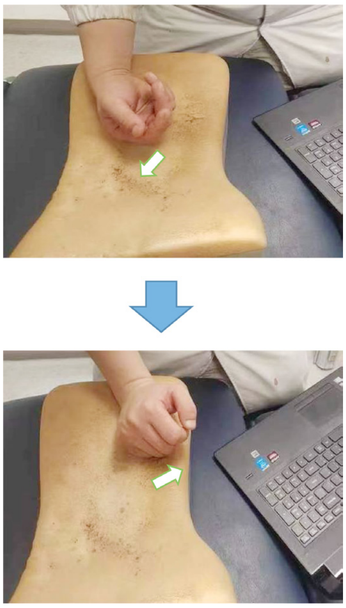
Appendix 1.

Basic operation of the rolling manipulation



1. In the first step of the rolling manipulation, the thumb is naturally straight and the remaining four fingers are flexed, with the angle of flexion decreasing in turn, reaching approximately 90 degrees of flexion at the metacarpophalangeal joints of the little finger and ring finger, so that the back of the hand is slightly arched to form a rolling contact surface.



2. In the second part, the wrist joint is relaxed and a compound movement of wrist flexion and extension is created by active pushing of the forearm. The hand is first swung out, with the wrist flexed at an angle of approximately 80°. The hand is not allowed to leave the skin and a continuous and sustained rolling pressure is created.

3. After the forearm has driven the wrist joint to produce an outward swing, it is necessary to perform an inward swing, which extends the wrist by approximately 40°. The whole operation is performed from the neutral position to the external swing and finally to the internal swing, forming an overall rolling operation. The ratio of pressure between the external and internal swing is 3:1 and the frequency is 120–160 repetitions/min. Note that the hand needs to be suction set on the treatment area.

Overall experimental method of operation

The rolling manipulation site was chosen to be in the left lower limb gastrocnemius, and the intervention site was kept consistent across all participants to avoid variability in the experimental data.

The participants lay prone, and the lower leg of the left lower limb was placed on the force-measuring table of a type II Tuina manipulation tester. The operating physician stands to the right of the participant and performs a rolling manipulation on the participant's left lower limb (A).

The pressure, frequency and duration of the procedure were selected according to an orthogonal table and the gastrocnemius muscle of the left lower limb was manipulated by rolling manipulation. Three orthogonal tests were conducted in this experiment. Based on the parameters of the commonly used clinical rolling manipulation, initial values of 2, 4, and 6 kg pressure, frequencies of 60, 120, and 180 repetitions/min and durations of 5, 10, and 15 min were determined for the first round of tests. For example, a pressure of 2 kg, a frequency of 60 repetitions/min and a duration of 5 minutes is a combination, and so on. The optimal combination of parameters is screened according to haemodynamic indices, with the criterion of promoting greater blood flow.

At the same time, the pressure, frequency and duration parameters of the manipulation were collected simultaneously by the type II Tuina manipulation tester and timer to verify the accuracy of the manipulation (B).