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Analysis of biomechanical characterization of the thumb rubbing method

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Abstract.
BACKGROUND: Thumb rubbing is one of the widely accepted massage techniques, owing to its simple and effective operation. Exploring the biomechanical characteristics of the thumb rubbing method can assist the understanding of the operating characteristics of manipulation, thereby improvising the therapeutic role of manipulation.
OBJECTIVE: To study the kinematic and kinetic characteristics of the thumb kneading method from the biomechanical point of view, and to quantitatively analyze the key points of thumb kneading operation.
METHODS: We explored the biomechanical characteristics of the thumb kneading operation by an analysis of the parameters scored by the experts and students using the "thumb kneading data glove and data collection system".
RESULTS: (1) Force trajectory: The expert group showed a regular force trajectory compared to the student group, with a stable thumb suction position, small drift and concentrated force. (2) Force value: The average force value of the expert group was concentrated in the range 0.614 ± 0.041 kg, while the average force value of the student group was concentrated in the range 0.650 ± 0.146 kg and the difference was not statistically significant. (3) Frequency: The frequency of the expert group was mainly concentrated in the range 134.280 ± 39.106 times/min, while that of the student group was 66.04 ± 23.651 times/min, ($P < 0.05$). (4) Period: The operation cycle during the thumb kneading of the expert and student groups was mainly concentrated in the range of 0.476 ± 0.117 s and (0.990 ± 0.259) s, respectively, and the difference was statistically significant ($P < 0.05$).
CONCLUSION: The present study revealed that the technical operation of the expert group was more stable and standardized than that of the student group. It was found that the force value was inversely proportional to the frequency of the operation. In the "circular rotation" operation of the thumb rubbing method, the force value conversion degree of different parts of the thumb reflected the motion trajectory. Furthermore, the "circular rotation" operation performed by the expert group was better than the student group. The study of the parameters, including the angle of frequency, period and force value can reflect the biomechanical characteristics of thumb rubbing method to a significant extent.

Keywords: biomechanics, thumb rubbing, mechanical characteristics

1. Introduction

TuiNa is a mechanical stimulation therapy that utilizes a certain degree of thumb kneading to create a mechanical pressure on the muscle tissue. Mechanical stress affects the nerve excitability and offers a relaxation response. On the other hand, it increases the blood flow by increasing the arterial pressure and muscle temperature, maintaining a benign thermal stimulus [1]. Mechanical stimulation enables the

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muscle tissue to transmit signals from the central nerve transduction and stimulation sites to the spinal dorsal horn by sensory nerves and spinal nerves through a sensorimotor feedback loop, leading to a series of positive body changes [2]. In the study of TuiNa, biomechanical methods can be utilized to study the complex thumb kneading and its mechanical effects. The use of the kinematic and kinetic characteristics of the thumb kneading operation can assist the standardization of the thumb kneading manipulation method [3].

Thumb kneading is a very widely used massage technique in clinical practice. The utility model has the advantages of convenient operation, wide application range, small contact area and concentrated skills. It can be operated on specific meridians or tender points throughout the body. It can dredge the meridians, promote *qi* and blood circulation, calm the mind, and replenish *qi* in the intestines and stomach. Furthermore, it offers a wide acceptance and can be applied in practice to realize the quantification of thumb friction method, thereby providing a better means and method for future research and development. At present, the biomechanical research on thumb kneading manipulations mainly focuses on the spinal joint manipulations and soft tissue release manipulations. The research methods employed mainly include the finite element model [4], solid mechanics [5], and the multi-rigid body mechanical model [6] to explore the characteristics of thumb kneading manipulation. The methods used in the above studies are difficult to be replicated in the real muscle and soft tissue, and the mechanical results derived can be inevitably biased. Aiming at these shortcomings, the present study employed the thumb kneading method in the soft tissue manipulation as the research object. Using the "thumb kneading manipulation data glove and data acquisition system" developed by the Shanghai University of Traditional Chinese Medicine, the real manipulation in human body was performed, in order to restore the real operating environment and quantify the operating points of the thumb kneading method.

2. Test method

2.1. Test instruments

Manipulative data glove and data collection system: It was developed by the Shanghai University of Traditional Chinese Medicine Engineering Teaching and Research Office.

2.2. Test contents and methods

2.2.1. Test object

Expert group: 10 professional doctors who had been engaged in clinical practice for more than 15 years.

Student group: 10 students majoring in Massage from Shanghai University of Traditional Chinese Medicine.

Volunteers: 10 healthy male students of the Shanghai University of Traditional Chinese Medicine, who did have any obvious contraindications of massage.

2.2.2. Outcome measure

Thumb rubbing method: The outcome measures included the Time-force waveform (mean force), Period and Frequency of the detection point.

2.2.3. Test method

The gloves were connected to the data acquisition software before testing, and the ELVIS II master power switch and prototype board switch was opened. The sampling rate was set at 1000 Hz, and the

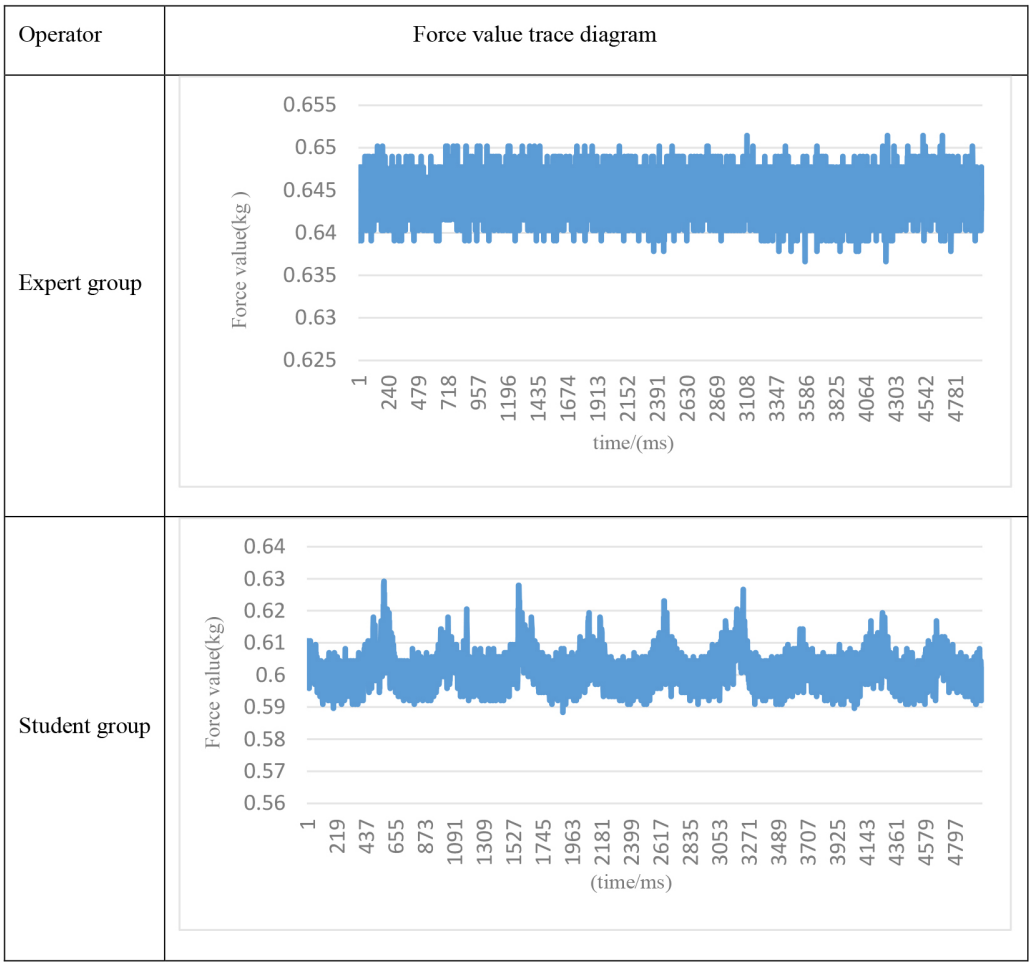

Fig. 1. Knead mana value trajectory.

chiropractors and volunteers were informed not to exercise vigorously 1 day before the test. During the test, the operator wore the thumb kneading data glove. After a rest of 5 min, the thumb kneading operation was carried out according to the operation requirements of the kneading method in the textbook "Thumb kneading Manipulation" [7]. The operator performed continuously for 5 min each time, and collected data continuously for 3 times, with an interval of 3 min for each acquisition.

2.2.4. Statistical methods

Three groups of data collected from doctors and students was screened, and the most stable group was selected; the middle 10 s were intercepted to obtain the waveform and data. The SPSS21.0 statistical software was used to quantitatively analyze the mean value of the manipulator's mana, and the test level $\alpha = 0.05$ was set. The statistical index describing the central tendency was the mean, and the discrete trend was the standard deviation. The normality test was conducted on the data of the expert group and the student group, which met the normal distribution. The paired sample t-test was used for the two groups, and the Wilcoxon signed rank test was used for the paired data, if the data did not obey the normal distribution.

Table 1
Kneading mana value parameters

Group	Average value	P value
Experts ($n = 10$)	0.614 ± 0.041	0.959
Students ($n = 10$)	0.650 ± 0.146	–

Table 2
Kneading frequency and period

Group	Frequency	Period
Experts ($n = 10$)	134.280 ± 39.106	0.476 ± 0.117
Students ($n = 10$)	66.04 ± 23.651	0.990 ± 0.259
P value	0.007▲	0.009□

Note: #: Wilcoxon signed rank test for paired data was used when the normal distribution was not observed. Students group and experts group frequency comparison, ▲$P < 0.05$, student group and expert group period comparison, $P < 0.05$.

3. Results

3.1. Kneading force trajectory

As shown in Fig. 1, the kneading magic value of the expert group was concentrated in the range 0.5–0.7 kg, while the kneading magic value of the student group was mainly concentrated in the range 0.5–1.5 kg. It was found that the expert group knead magic value track was regular, the thumb suction position was stable, the drift was small, and the force was concentrated. However, in the student group kneading method operation, the thumb suction position was not enough, the position was drifting, and the force was not stable and concentrated.

3.2. Analysis of the kneading force trajectory value

It was observed that the average force value of the kneading method of the expert group was smaller than that of the student group, and the difference was not statistically significant ($P > 0.05$; Table 1). The dispersion of the force value of the expert group was smaller than that of the student group. It can be considered that there was no difference in the force value of the kneading operation between the expert group and the student group, but the force value of the expert group was more stable than that of the student group.

3.3. Kneading frequency and period diagram

The frequency of one of the 10 experts was 228 times/min, and the frequency of the other 9 experts was in the range 90–150 times/min (Figs 2 and 3). One student in the student group had a frequency of 116 times/min, while the other 9 students had a low frequency in the range 50–90 times/min. The period of the expert group was about 0.5–0.6 s, and the period of the student group was about 0.5–1.2 s. The period of the expert group was less than that of the student group.

3.4. Analysis of kneading frequency and period data

Table 2 presents the comparison of frequency of the expert and student groups. The frequency of the expert group was higher than that of the student group, and the difference was statistically significant

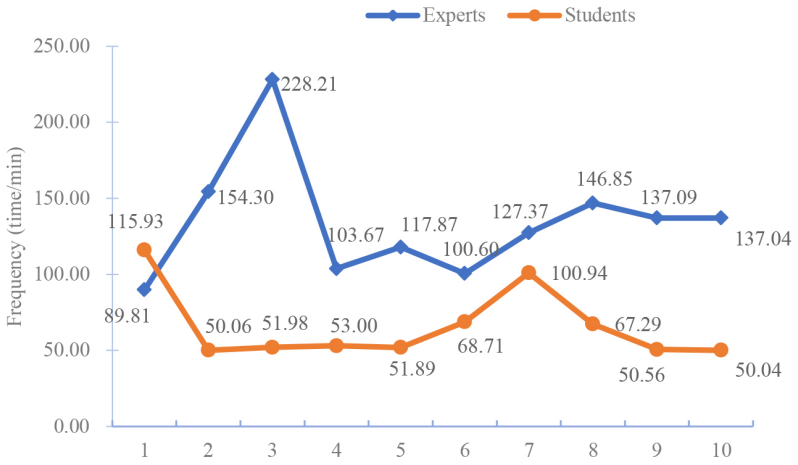

Fig. 2. Average value of thumb kneading (time/min).

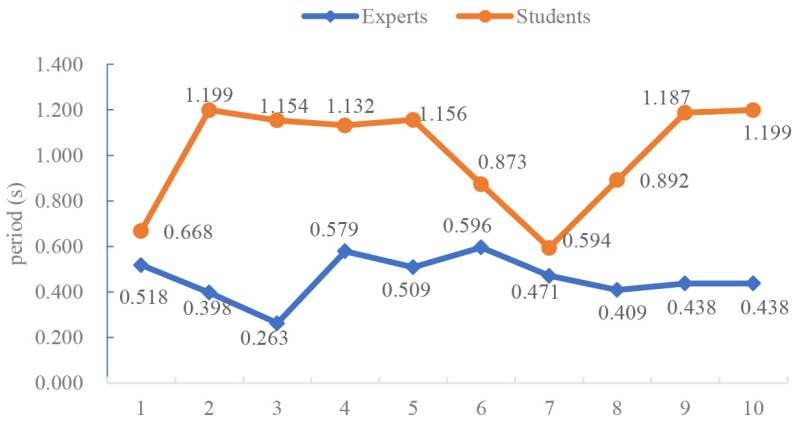

Fig. 3. Period diagram of kneading method (S).

($P < 0.05$). The expert group had a shorter period than the student group. Thus, it can be considered that the expert kneading exhibited a small operation period and a stable frequency.

4. Discussion

4.1. Force value and force trajectory

The essential feature of TuiNa is that "force" acting on the body surface leads a biological effect in the body through mechanical effect [7]. Therefore, the "force" of the manipulation is a key factor to generate the stimulus, and the effective force of manipulation needs to meet the three elements of force: size, direction and position of action [8]. The force exerted by TuiNa on the body exhibits a process of dynamic change, and the manipulation force is adjusted according to the subjective feeling of "*qi*" of patients, that is, "acid, numbness, swelling, pain" and other feelings [9]. This sense of "*qi*" makes the massage present its effect by relieving body fatigue [7], analgesia [10], alleviating chronic pain caused

in many diseases [9,11], and enhancing body immunity [12]. Therefore, it is necessary to consider the strength of the manipulation force, in order to promote the body to produce "*qi*" induction.

Thumb kneading is based on the thumb thread surface as the point of force with gentle rotation that gets absorbed by the body surface [13]. Therefore, the operation points of the thumb kneading can be summarized as "absorbing" and "returning", and the three elements of the binding force. It can be considered that in the operation of the thumb kneading method, the force exerted is the compound force of multiple directions. Relevant studies [14,15] showed that the application direction of thumb kneading includes the vertical force and horizontal force. The ZTC-I intelligent massage measurement instrument is used to measure the vertical force, front and back horizontal force, and left and right horizontal force of thumb kneading method. Subsequently, the corresponding three-dimensional mechanical space parameters are obtained. The force value measured in the present study was mainly horizontal force. It was found that in the return movement, the horizontal force difference in different directions is small, but the measured vertical force is weak or even 0, which may be due to the data error caused in the *in vitro* test, or due to the the unique force application skills of different massage schools.

The glove-type measuring instrument used in this study carried out a real-time thumb kneading operation *in vivo*. By collecting the manipulation data of experts and students, it was found that during the operation process of kneading method, the force value for the expert group in was concentrated in the range 0.5–0.7 kg, and was in the range of 0.5–1.5 kg in the student group. Considering that the force value in this operation has a single change, the difference in the force value during the process of rotation is small; hence, this study focused on analyzing the average force value of the thumb kneading method. The average force value of the expert group was 0.614 ± 0.041 kg, the average force value of the student group was 0.650 ± 0.146 kg. Although the force value of the expert group was smaller than that of the student group, the comparison between the two was not statistically significant. From the dispersion analysis, it can be considered that the operating force value of the expert group was more stable and concentrated than that of the student group. The force values measured by the two groups included mainly the vertical force, which is somewhat different from the previous studies. This is because in the manipulation of the human body surface, the primary operation is that the operator should effectively adsorb the treatment site, in order to avoid the beating and detachment of the operator from the treatment site, which may lead to the ineffective work of the manipulation. It can be seen from Fig. 1 that the contact surface of the thumb thread surface changes accordingly at the time of the "return rotation" operation, and the force on the corresponding part changes. This shows that during manipulation, the force value is in a dynamic change process. Further, it was found that the force value of thumb kneading method exhibited a single change, and the waveform height of the expert group's manipulation was uniform, as against the wave peak of the student group that showed a rise and fall. In accordance with the method of operation of the expert group, the horizontal height difference of the manual peak and valley waveform was small. Combined with the drift degree of force value in the absorption position, it reflects the operation points of the thumb kneading method of "absorption" and "return rotation" and the trajectory for circular or oval research.

4.2. Frequency

Frequency is one of the dynamic characteristics of the massage manipulation. When manipulation is applied to the body surface at a certain frequency, a random periodic signal gets generated on the body surface, which has a biological resonance effect with the infrasound frequency of the internal organs [16]. This effect produces certain effect on the internal osmosis, and previous studies have shown

that at a certain frequency can affect the blood flow and blood viscosity, thereby proving the fact that the manipulation techniques have the "deep" effect. This influence on the soft tissue viscoelastic material and the biomechanics characteristics related to the deep effect at low frequencies has been studied earlier [20,21]. Low-frequency manipulations can excite parasympathetic nerves, resulting in sedative and inhibitory effects [19]. This proves that when the manipulation is maintained at a certain frequency, the manipulation therapy exhibits an osmotic effect. Current studies on manipulation frequency [17] propose that the manipulation frequency should be kept at 50–80 times/min to achieve the effect of deep massage, which can make the manipulation present a deep effect. However, most studies [18] believe that the kneading frequency should be 120–160 times/min. In the study of the frequency of thumb kneading of different schools [15], it was found that the operation frequencies of children school, bone injury school and tendon injury school were 55 times/min, 112 times/min and 165 times/min, respectively, from slow to fast. Therefore, on the basis of biomechanics, it can be considered that different manipulation frequencies should be used for different age-groups of people (ignoring the precision of the instrument).

In this study, the frequency of the expert group was mainly concentrated in the range 134.280 ± 39.106 times/min, and 66.04 ± 23.651 times/min for the student group, which was statistically significant ($P < 0.05$). Combined with the force value analysis of the two groups, it was found that the force value of the student group with slower frequency was larger, while the force value of the expert group with a higher frequency was less. This is because on the premise of performing the same manipulation, the muscle contraction speed is proportional to the speed of manipulation frequency. Combined with the actual biomechanical effect, it was found that relevant studies showed that the operation frequency of 50–80 times/min made the manipulation produce a deep effect, but the force value generated under this frequency was relatively large, which was consistent with the study of thumb kneading method of the student group. While the study cannot prove, whether a deep effect was exhibited, but maintaining the uniformity of the manipulation of a stable point can make the technique to achieve a deep effect, though this conclusion still needs to be validated by further clinical research.

4.3. Period

As one of the kinematic characteristics of the thumb kneading manipulation, the period parameter reflects the stability of manipulation to a certain extent. In this study, the operation cycle during the thumb kneading of the expert and student groups was mainly concentrated in the range of 0.476 ± 0.117 s and (0.990 ± 0.259) s, respectively, and the difference was statistically significant ($P < 0.05$). It was found that the operation cycle of the expert group was faster than that that of the student group. From to the analysis of dispersion of the cycle value, the dispersion of expert group was smaller than that of the student group; hence, the operation cycle of the expert group was more stable than that of student group. From the observation of the periodic waveforms of the two groups of manipulations, the periodic waveforms of the expert group were more stable and uniform. In conclusion, it can be considered that the thumb kneading of the expert group was uniform and stable, which can better reflect the stability of the thumb kneading method.

5. Conclusion

The present study conducted a real-time *in vivo* study on the operating points of thumb kneading in different groups. The force value drift degree characterized the degree of fixation of the operator on the treatment site. It was found that the force value drift of the student group was larger, while that of the

expert group was smaller. Thus, the force values the experts were concentrated, thereby reflecting the stable degree of fixation on the treatment site by the expert group. The difference between the peak and valley levels of the force value can be considered as the "return rotation" operation of thumb kneading. The degree of force change in different parts of the thumb reflected the movement track of the thumb, when the thumb kneading method was performed. According to the differences in the peak-valley level of force values between the experts and the student group, it was found that the difference in the peak-valley level waveforms of the expert group was small, while they were large in the student group. Therefore, it can be considered that the expert group could better interpret the operation points of thumb kneading "return rotation". However, the trajectory of the manipulative waveform of the student group could not well reflect this point. From the drift degree of the binding force value and the difference of the peak-valley waveform, we believe that the degree of "fixation" of the operator to the operation site can affect the manipulative configuration.

In the biomechanical study of TuiNa, the frequency of thumb kneading is proportional to the speed of muscle contraction of the operator, resulting in different force values. The results of the present study test also verified this conclusion. As a kind of external therapy directly acting on the body, the relevant biological effects due to the thumb kneading manipulation on the body can provide an understanding of the operating points of massage manipulation.

Ethical compliance

Research experiments conducted in this study with animals or humans were approved by the Ethical Committee and responsible authorities of our research organization following all guidelines, regulations, legal, and ethical standards as required for humans or animals.

Conflict of interest

The authors have no conflicts of interest to declare.

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