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Exploratory Research on Quantitative Parameters of Sheng's Acupuncture and Moxibustion Technique based on Wearable Acupuncture Pressure Sensor

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Abstract: ***Objective: To investigate and analyze the unique needling technique characteristics of Sheng's by acquisition of quantitative parameters of needling technique based on a wearable needling pressure sensor device. Methods: The wearable acupuncture pressure sensor device and the matching acupuncture technique acquisition system were used to collect the lifting and insertion pressures on acupuncture needles, twisting moments, and finger pressures on needle handles during bilateral ChiZe (LU5) acupoint acupuncture in 30 subjects by Sheng's acupuncture technique inheritance and acupuncture clinicians, and the characteristics of their techniques were analyzed and compared. Results: Sheng's acupuncture technique downward insertion pressure, twisting torque and lifting insertion frequency parameters were significantly greater than those of the acupuncture clinician's(P<0.05). Thumb and index finger pressure and force application frequency parameters were significantly greater than acupuncture clinician's (P<0.001). Middle finger pressure and frequency of force application were significantly less than the finger force application parameters of acupuncture clinician(P<0.05). Conclusion: Based on wearable needling pressure sensor device and needling technique acquisition system can objectively and stably represent doctors' needling techniques and embody the characteristics of different needling techniques. It is initially believed that Sheng's needling technique is characterized by heavy insertion and deep stabbing after needle entry, rapid twisting, greater finger force of the thumb and index finger, and faster frequency of force application. It can provide a data-based and visualized objective basis for further exploring the characteristics of acupuncture techniques of famous veteran Chinese medicine practitioners and the inheritance of Sheng's acupuncture techniques.***

Keywords: Quantification of acupuncture manipulation, Needling pressure sensor, Operational stability, Sheng's acupuncture manipulation, Manipulation characteristics**.**

1. Introduction

Professor Sheng Canruo, a national famous old traditional Chinese medicine doctor, the first "famous teacher of traditional Chinese medicine" in Jiangsu Province, studied under Professor Cheng Dan'an, the founder of Chengjiang School, and Professor Qiu Maoliang, who has been engaged in acupuncture and moxibustion clinical, teaching and scientific research for nearly 70 years. Professor Sheng Canruo is one of the representatives of Jiangsu acupuncture and moxibustion. He has created original acupuncture techniques such as "Mian San Zhen" and "Yan Si Zhen". He is good at making good use of acupuncture and supplemented by many methods. He pays special attention to the application of meridian theory and acupuncture techniques [1]. Professor Sheng Canruo is nearly 90 years old, and his unique acupuncture method needs to be passed on.

As the basis of acupuncture and moxibustion, acupuncture techniques are diverse and rich. Different acupuncture techniques can produce different therapeutic effects, which is the key to affect the efficacy of acupuncture [2], and is also the key and difficult point in the teaching and inheritance of acupuncture [3]. At present, the teaching and inheritance of traditional acupuncture techniques are mainly learned by teachers in the way of dictation and consulting written records. Due to the differences in doctors' understanding and operating habits, there are certain differences in the walking methods of different doctors, and there is no standardized teaching and inheritance basis.

To address the lack of objective quantitative basis for acupuncture manipulation, in recent years, acupuncture scholars at home and abroad have developed a variety of acupuncture manipulation testers based on modern technology, which can be classified into off-body acupuncture manipulation testers and on-body acupuncture manipulation testers according to the different bodies of action [2]. As a typical physico-mechanical stimulus [4-6], our team believes that the essence of acupuncture is the mechanical force effect. Tang Wenchao [3, 7] and others believed that the physical parameters affecting the action of needling manoeuvre mainly include amplitude, frequency and force on the body of the needle. Ding Guanghong [8] et al. believed that the process of applying needles on a living human body is closely related to the active activities of life, and that the force on the body of the needle can be collected to determine the needling technique. The parameters obtained from the same needling technique applied to the same point on the human body by different needling practitioners are both similar and different. Based on the above viewpoint, our team cooperated with Southeast University to independently develop an on-body wearable acupuncture pressure sensor and acupuncture technique acquisition system, which consists of two parts: an acupuncture 2D force sensor and a glove pressure sensor. Among them, the acupuncture two-dimensional force sensor can collect the lifting and insertion pressure, twisting torque and frequency on the needles during the acupuncture treatment by the clinician, and record the changes of pressure and torque in the form of data [9]. In this study, the needling

techniques of Sheng's acupuncture inheritors and acupuncture clinicians were collected and quantitatively compared, aiming at initially exploring the uniqueness of Sheng's acupuncture, making preliminary preparations for the next step of collecting Sheng's old needling techniques, promoting the inheritance and teaching of Sheng's acupuncture, and paving the way for standardised teaching and inheritance of needling techniques.

2. Quantitative Acquisition of Clinical Acupuncture Manoeuvre Parameters

2.1 Wearable Acupuncture Pressure Sensor

During needling, a force f exerted by the physician acts on the needle, which comes into contact with the skin tissue, which produces a damping force f. Because the needle is light and has an acceleration that tends to 0, the force on the needle can be considered to approximately satisfy the equation F = -f. The needle is mainly subjected to friction, and the direction of the force, which is in the opposite direction of the needle's motion, will always impede the needle's movement. The sensor is mounted on the needle and therefore the force measured by the sensor is the resistance f [10].

Based on the above principles, Southeast University and our team collaborated to independently develop a needling pressure sensor and a needling manoeuvre measurement system (hereinafter referred to as the measurement system) to collect needling manoeuvre parameters. The sensor weighs only 3g and can be mounted on acupuncture needles to measure the lifting and insertion force and torque during needling, which has the advantages of small size, light weight, high precision, and convenient needle exchange compared with the traditional miniaturised multi-dimensional force needling sensors. Previous studies have shown [9] that the sensor has high accuracy and can accurately acquire the needle insertion pressure data during the needling process. The measurement system consists of a needling 2D force sensor (Fig. 1a), and a finger pressure sensor (Fig. 1b). During the needling process, the lifting and insertion pressure is generally within the range of±1.5 N, and the horizontal twisting moment±1.5 N/mm. 1-1.5 times of the sensor measurement range should be reserved when the sensitivity reaches the requirement. Therefore, we take the acquisition range of the vertical insertion pressure as ±3N, the acquisition range of the horizontal twisting moment as±3N/mm, and the acquisition range of the finger pressure sensor as 0N-2N.

2.2 Collection of Acupoints

With reference to the "Jing Xue Ming Cheng Yu Ding Wei" [11] (GB/T 12346-2021) issued by the National Standardization Administration Committee in 2021, 30 healthy subjects were selected to collect acupuncture manipulation parameters at bilateral Shakuzawa points. Shakuzawa point is the merging point of the hand Taiyin lung meridian. The meaning of 'merging' is confluence, and the meridian qi is abundant, so it is easy to obtain qi in depth and has the characteristics of convenient access to the point.

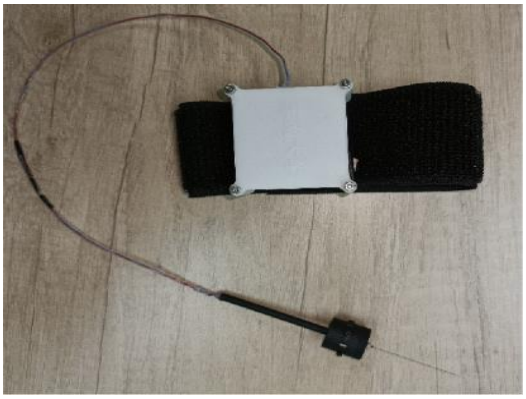
2.3 Acquisition Method

The collection was performed without strong light, strong noise and electromagnetic source interference in the surrounding. The subject enters the collection room, takes a sitting position, exposes the bilateral elbow joints and puts them on the treatment bed. After correctly wearing the sensor equipment, the administrator sterilised the subject's bilateral ulnar ze points and then performed the needling technique for 15s on each side (the subject's ulnar ze points were sore and swollen), replaced the disposable acupuncture needles and collected the next subject's data.

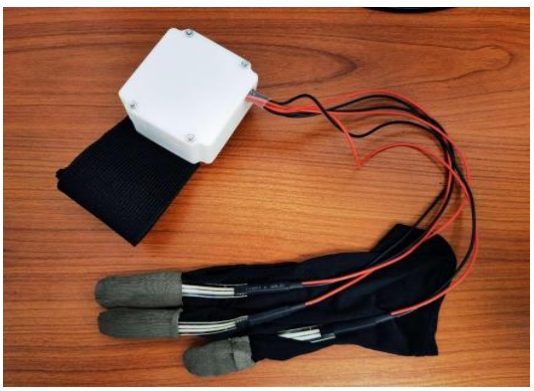
2.4 Quantitative Analysis Methods and Statistical Methods

MATLAB data analysis software was used. The data recorded by the measurement system was imported into the MATLAB software, due to the natural fluctuations of the collected data, the data was denoised using the method of superposition averaging, and then the instantaneous frequency of the force and moment was obtained using the Hilbert transform [9] to maximally avoid the influence of natural fluctuations on the results, and finally the pinprick manipulation was presented in the form of visualised waveform graphs and data.

The processed data were statistically analysed using SPSS27.0 software. Measurement information was expressed as mean ± standard deviation (x±s) or quartiles (M(P25, P75)). The paired t-test was used for intra-group comparisons of measures that met normal distribution, and the two independent samples t-test was used for inter-group comparisons. The rank-sum test was used for inter-group and intra-group comparisons of measures that did not meet normal distribution.



a Needle-punched b Glove pressure sensor



two-dimensional force sensors

Figure 1

3. Results

3.1 Comparison of Acupuncture Manipulation Parameters at Bilateral Chi Ze Points by Acupuncture Clinicians on Subjects

There was no statistically significant difference in the lifting pressure, clockwise twisting torque, lifting insertion and twisting frequency of bilateral ulnar ze acupoints (P>0.05), as shown in Table 1, which shows the stable lifting insertion and twisting needling manoeuvres of acupuncture clinicians in needling bilateral Chi ze acupoints of the subjects.

The differences in thumb, index finger and middle finger pressure and frequency of thumb, index finger and middle finger force application by the acupuncture clinicians were not statistically significant (P>0.05), as shown in Table 2, which shows that the acupuncture clinicians' finger force application manipulation practices were stable in needling subjects' bilateral Chi ze points.

3.2 Comparison of Acupuncture Manipulation Parameters of Bilateral Chi Ze Points in Sheng's Acupuncture Subjects

There was no statistically significant difference in the uplift pressure, downward insertion pressure, twisting torque and frequency of uplift, insertion and twisting at bilateral Chi ze points (P>0.05), see Table 3, Sheng's needle method inheritors in needling subjects with bilateral Chi ze points with stable uplift, insertion and twisting needling manoeuvres.

The differences between the thumb, index finger and middle finger pressure and the frequency of force application by the thumb, index finger and middle finger of the inheritors of Sheng's acupuncture were not statistically significant (P > 0.05), see Table 4, Sheng's acupuncture inheritors had a stable manipulation technique of applying force by the fingers in needling the bilateral Chi ze points of the subjects.

Table 1: Comparison of the lifting and twisting manoeuvres used by acupuncture clinicians to needle subjects at bilateral Chi ze points (x±s/M(P25, P75))

Group	Left Shakuzawa point(N=30)	Right Shakuzawa point(N=30)	t/Z vaule	P vaule
Upward pressure(N)	-0.0155(-0.0599, 0.0003)	-0.0588(-0.1196, -0.0369)	-1.800	0.072
Downward pressure(N)	-0.0182(-0.1211, -0.0023)	-0.1633(-0.2276, -0.1289)	-3.713	<0.001
Clockwise twisting torque(N/s)	0.0252±0.0139	0.0245±0.0176	0.249	0.600
Counterclockwise twisting torque(N/s)	-0.0093±0.0174	0.0025±0.0216	-3.902	0.001
frequency of lifting and inserting(Times/s)	1.4337±0.5612	1.2875±0.5113	1.373	0.180
Twisting frequency (times/s)	1.6515±0.5192	1.6231±0.4213	0.316	0.754

Table 2: Comparison of finger force applied by acupuncture clinicians to subjects needled at bilateral Chi ze points (x±s/M(P25, P75))

Group	Left(N=30)	Right(N=30)	t/Z vaule	P vaule
thumb pressure(N)	0.0743(0.0649,0.0954)	0.0661(0.0570,0.0791)	-1.683	0.092
index finger pressure(N)	0.0513±0.0130	0.0496±0.0124	0.539	0.593
middle finger(N)	0.0779±0.0214	0.0747±0.0194	0.720	0.477
Thumb force application frequency (times/s)	1.4768±0.4413	1.4903±0.4011	-0.119	0.906
Index finger force application frequency (times/s)	1.4591(1.1948,1.7368)	1.5959(1.1782,1.8464)	-1.253	0.210
Middle finger force applicationfrequency (times/s)	1.3963±0.3600	1.4091±0.4049	-0.126	0.900

Table 3: Comparison of lifting and twisting manoeuvres for bilateral Chi ze point needling in subjects by the inheritors of Sheng's acupuncture (x±s/M(P25, P75))

Group	Left(N=30)	Right(N=30)	t/Z vaule	P vaule
Upward pressure(N)	-0.1037(-0.2090, -0.0037)	-0.0780(-0.1387, -0.0209)	-1.306	0.192
Downward pressure(N)	-0.1854±0.1289	-0.1489±0.0705	-1.549	0.132
Clockwise twisting torque(N/s)	-0.0205±0.0419	-0.0095±0.0644	-0.896	0.378
Counterclockwise twisting torque(N/s)	-0.0274(-0.0823, -0.0110)	-0.0318(-0.0784, 0.0182)	-1.080	0.280
frequency of lifting and inserting(Times/s)	1.2016(0.8967, 1.7990)	1.4535(1.0478, 2.1572)	-1.573	0.116
Twisting frequency (times/s)	1.5152±0.4435	1.4682±0.4153	0.276	0.784

Table 4: Comparison of the characteristics of finger force application by the inheritors of Sheng's acupuncture on subjects needled at bilateral Chi ze points (x±s/M (P25, P75))

Group	Left(N=30)	Right(N=30)	t/Z vaule	P vaule
Upward pressure(N)	0.2153(0.1440,0.4125)	0.1836(0.1070,0.2729)	-1.861	0.063
Downward pressure(N)	0.1141(0.0761,0.1930)	0.1093(0.0854,0.2158)	-0.195	0.845
Clockwise twisting torque(N/s)	0.0730±0.0220	0.0644±0.0204	1.725	0.095
Counterclockwise twisting torque(N/s)	1.0345±0.4799	1.0553±0.4025	-0.192	0.849
frequency of lifting and inserting (Times/s)	1.1039±0.3043	1.2023±0.4308	-0.934	0.358
Twisting frequency (times/s)	1.0401±0.3288	1.0854±0.3892	-0.476	0.638

3.3 Comparison between Sheng's Acupuncture and Acupuncture Clinicians' Needling Technique Parameters

Sheng's needle method has the characteristics of lower insertion pressure, twisting torque and lifting and insertion frequency are greater than the acupuncture clinician's acupuncture manoeuvre parameters during the needling process, and the difference is statistically significant (P<0.05). The twisting frequency was slightly greater than the acupuncture clinician's needling manoeuvre parameters, but the difference was not statistically significant (P>0.05), as shown in Table 5. At the same time, Sheng's needling was greater than the acupuncture clinician's finger force application parameters during needling in terms of thumb and forefinger pressures and frequency of force application, and the difference was statistically significant (P<0.001). The

middle finger pressure and frequency of force application were less than the finger force application parameters of the acupuncture clinicians, and the difference was statistically significant (P<0.05), as shown in Table 6.

Table 5: Comparison of lifting and twisting manoeuvres for needling bilateral Chi ze points in subjects by Sheng's acupuncture inheritors and acupuncture clinicians (x±s/M(P25, P75))

Group	Sheng's Needlework Inheritors(N=60)	Acupuncture and moxibustion clinicians(N=60)	t/Z vaule	P vaule
Upward pressure(N)	-0.0425(-0.0850, -0.0126)	-0.0439(-0.1086, -0.0036)	-0.562	0.574
Downward pressure(N)	-0.1945±0.0988	-0.1297±0.1154	-3.302	0.001
Clockwise twisting torque(N/s)	0.0199±0.0164	0.0014±0.0241	4.899	<0.001
Counterclockwise twisting torque(N/s)	-0.1248(-0.2128, -0.0063)	-0.0042(-0.0153, 0.0092)	-2.115	0.034
frequency of lifting and inserting(Time/s)	1.2954(0.8958,1.7603)	0.9781(0.7133,1.6329)	2.855	0.005
twisting frequency (Time/s)	1.6373±0.4690	1.4712±0.4872	1.902	0.060

Table 6: Comparison of the characteristics of finger force application by Sheng's acupuncture inheritors and acupuncture clinicians for needling subjects at bilateral Chi ze points (x±s/M(P25, P75))

Group	Sheng's Needlework Inheritors(N=60)	Acupuncture and moxibustion clinicians(N=60)	t/Z vaule	P vaule
thumb pressure(N)	0.1864(0.1165, 0.3383)	0.0691(0.0616, 0.0874)	-8.315	<0.001
index finger pressure(N)	0.1110(0.0787, 0.2023)	0.0502(0.0413, 0.0575)	-9.075	<0.001
middle finger(N)	0.0687±0.0215	0.0763±0.0203	-2.028	0.045
Thumb force application frequency (times/s)	1.4835±0.4184	1.0449±0.4392	-5.695	<0.001
Index finger force application frequency (times/s)	1.4809±0.3686	1.1531±0.3731	-4.920	<0.001
Middle finger force applicationfrequency (times/s)	1.0628±0.3579	1.4027±0.3801	-5.118	<0.001

4. Discussion

Throughout the various exploration methods established by the Institute on the Objective Evaluation of Acupuncture Techniques, after the early popularization of sensor technology based on electrical signal conversion technology, the discussion of acupuncture technique quantification from the perspective of "speed", "pressure" and "torque" is a necessary way to establish acupuncture technique quantization and visualization in the future [12]. However, most of the existing studies quantify the data of needling on the instrument and focus only on the movement of the acupuncture needle itself [7, 12-16], whereas the acupuncture manipulation itself mainly consists of two parts: the force on the needle body and the movement of the needle applicator's fingers during the needling process [4], so quantitative analyses of the pressure of the above two parts during the needling process at the same time are closer to the real acupuncture diagnosis and treatment process. Studies have shown that the needling process is closely related to the subjective activities of human life (e.g., muscle contraction, mental tension, external environmental factors, etc.) [8]. Therefore, there is still a certain degree of difference between the action of acupuncture needles on the human body and the action of off-body manipulation collection instruments. This research is based on wearable on-body needling pressure sensors to collect the movement of the needle body and the movement of the fingers during the needling process of clinicians, and to obtain the data of pressure, torque, movement amplitude and stability through the needling manoeuvre acquisition system. Compared with existing studies, more parameters are observed and the data acquisition is closer to the actual clinical diagnosis and treatment operation. At the same time, the next step will be to collect the waveform diagrams of the acupuncture techniques generated during the acupuncture process, which will facilitate the further inheritance and research on the acupuncture techniques of the famous veteran Chinese medicine practitioners.

Acupuncture technique is a key factor in determining the efficacy of acupuncture, and relevant studies have shown that acupuncture techniques are ideal for the treatment of most clinical diseases, but different acupuncture techniques produce different effects and form different amounts of stimulation [17]. In acupuncture manipulation, the force on the body of the needle and the needle finger force are important parts of it; according to the different directions of the force during acupuncture, it can be divided into the vertical pressure acting on the body of the needle, the twisting moment, and the pressure of the thumb, forefinger, and middle finger acting on the handle of the needle [18]. Based on the above points, the results of this study show that: (1) The wearable needling pressure sensor device developed by our team in cooperation with Southeast University, which acts on the human body, can stably collect the pressure and torque of the body of the needle, as well as the pressure parameters of the thumb, forefinger, and middle finger during the needling process. (2) It compared with the clinician's needling technique, Sheng's needling method had the characteristics of greater downward pressure, greater twisting torque, and faster frequency of lifting, inserting and twisting during the needling process. (3) It compared with the clinician's needling technique, Sheng's needling had the characteristics of more obvious force application and faster frequency of force application by the thumb and forefinger, but weaker force application and slower frequency of force application by the middle finger in the needling process. Among them, the characteristics of Sheng's needling technique with faster lifting and insertion and twisting frequency per unit time, higher lifting and insertion pressure and twisting torque, and the thumb and forefinger as the main application fingers of needling, were in agreement with the results of the previous study of Professor Sheng Canruo's clinical experience in acupuncture and moxibustion, which stated that 'one-time deep stabbing' and 'rapid twisting with the thumb after the entry of needles'[1, 19, 22].

In summary, the wearable acupuncture pressure sensor is able to collect and quantify these data, and at the same time has a high degree of stability, which can provide new ideas and directions for the inheritance and teaching of acupuncture techniques of famous old Chinese doctors. At present, the team has determined that the sensor can stably collect and

quantify acupuncture techniques, and has initially measured the clinical acupuncture techniques of Sheng's acupuncture inheritors. The next step will be to collect Professor Sheng Canruo's own clinical acupuncture techniques and quantitatively compare and evaluate them with those of many clinicians, so as to deeply explore the unique characteristics of Sheng's acupuncture techniques, to provide a new method for the determination and inheritance of acupuncture techniques of famous veteran Chinese medicine practitioners, to provide a favourable condition for the researcher to explore the characteristics of the techniques operated by other famous practitioners, and to provide a useful reference for the inheritance and teaching of acupuncture techniques.

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