

# Quantitative research technology of tuina manipulations

## 推拿手法的量化研究技术

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### Abstract

Tuina is a physical therapy for treatment and prevention of diseases. The predecessors had summed up the systematic tuina manipulations through experiences. In order to study the scientificity and usability of the technology, the researchers established a mathematical model of tuina manipulations, and used video technology to capture the trajectory of the manipulations. Using the mechanical sensor to sense the real manipulations, researchers developed a tuina manipulation instrument and obtained a lot of basic mechanics data about the manipulation technology. Through the summary of the research results of the predecessors, accurate, true and comprehensive mechanical parameters of technology of tuina manipulations were obtained to guide the research and development of instruments of tuina manipulations, and promote the development of the discipline of tuina science.

**Keywords:** Tuina; Massage; Science of Tuina (Traditional Chinese Medicine); Evaluation Studies; Computer Simulation; Transducers; Equipment and Supplies

**【摘要】**推拿是一种治疗和预防疾病的物理疗法。前人在不断的生活积累中总结出了系统的推拿疗法。为研究推拿的科学性和可用性,研究人员建立了推拿手法的数学模型,并利用视频技术捕捉手法轨迹,利用力学传感器感触真实手法,研发出了推拿手法检测仪器,获得大量有关推拿手法的基础力学数据。通过对前人的研究成果进行总结,以获得精准、真实、全面的推拿手法力学参数,用于指导推拿诊疗仪器的研发,促进推拿学科的发展。

**【关键词】**推拿;按摩;中医推拿学;评价研究;计算机模拟;传感器;设备和供应

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Tuina is a method to prevent and treat diseases by manipulations and/or performing specific physical movements. The *Yi Zong Jin Jian · Zheng Gu Xin Fa Yao Zhi (Essence of Bone-setting Method of Golden Mirror of Medicine)* (a traditional Chinese medicine classic) says, Tui-pushing means to push a certain part of body by hands to put it to the original place. Na-grasping means to pinch the affected area by one or two hands with light or heavy force to slowly restore its position<sup>[1]</sup>. The ancient people often suffered painful injuries in their work and life. They found that the pain could be alleviated or eliminated through tuina therapy, and through constant practice, they gradually formed a systematic technology of tuina manipulations.

## 1 History of Tuina

Tuina, of which the ancient name was An Mo (massage), An Qiao (An-pressing by hand or foot). There is a record of Qiao Yin (massage by hand or foot) in

*Shi Ji · Bian Que Cang Gong Lie Zhuan (Biography of Doctor Bian Que and Cang Gong in Historical Records)*, which should be classified into An Mo (massage) and Dao Yin (physical and breathing exercises). The birthplace of An Mo (massage) is the central plain region of China (now Henan area in China). The earliest written records of An Mo (massage) therapy in China are found on the oracle bones of Yin and Shang Dynasties. On the oracle bones, there are such names as Fu-patting, Mo-rubbing and Sao-scratching (Table 1).

**Table 1. Hieroglyphics related to tuina manipulations**

| Oracle  | Modern text | English translation |
|---|-------------|---------------------|
|  | 拊           | Patting             |
|  | 搔           | Scratching          |
|  | 摩           | Rubbing             |

As a formal professional name, An Mo (massage) was first seen in *Su Wen · Xue Qi Xing Zhi Pian (Relation Between Blood, Qi, Shape and Spirit in Essential Questions)*: numbness caused by fright leading to blockage of meridians should be treated by An Mo

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(massage), medicinal alcohol and herbs. It is the first time in history that An Mo (massage) has been clearly presented as a treatment. During Spring and Autumn Period and Warring States Period, An Mo (massage) had been widely used in the treatment of diseases, such as Bi-impediment syndrome, Jue-syncope syndrome, jaundice, hernia, etc. *Su Wen · Ju Tong Lun (Pain Theory in Essential Questions)* records that dispersing blood and qi and warming is the principle of massage therapy for some diseases caused by cold evil.

During Qin and Han Dynasties, the first massage therapy monograph known in China: *Huang Di Qi Bo An Mo Shi Juan (Ten Volumes of Massage by Huang Di and Qi Bo)* (lost) came out; during Wei, Jin and Tang Dynasties, the country set up a massage specialist, and the massage therapists began to appear; and during Sui Dynasty, the massage therapists were divided into three levels of doctors, masseurs and workers, and massage therapy was then gradually getting valued. *Qian Jin Yao Fang (Essential Prescriptions Worth A Thousand Gold)* in Tang Dynasty records that massage with herb cream should be done on the anterior fontanelle, center of hands and feet for children to prevent wind and cold after they getting up in the morning, which is an early documentary on the prevention of diseases by massage therapy. During Song, Jin and Yuan Dynasties, massage had been widely used as a treatment in various clinical fields. In Song Dynasty, therapist Pang An-shi used massage therapy to help pregnant women to induce labor, and the effect was remarkable. During Ming Dynasty, massage therapy ushered in a second peak of development<sup>[2-3]</sup>. At the beginning of Ming Dynasty, royal hospital established 13 medical subjects, and massage was one of them. For kids who were reluctant to receive herbs and acupuncture treatment, massage could achieve the purpose of treatment by regulating qi and blood circulation, and the function of spleen and stomach. Therefore, the clinical experience and theoretical knowledge of pediatric massage has been constantly improving. The first pediatric massage book in China: *Xiao Er An Mo Jing (Massage Classic for Children)* was also published in Ming Dynasty. However, in the fifth year of reign of Longqing Emperor (1571), the massage department was banned by the government. According to relevant historical materials and literature, the reason for the cancellation of the massage department may be due to accidents leading to some medical accidents, as well as the feudal tradition of ban of intimate touch between men and women. The development of massage had then entered a trough<sup>[4-6]</sup>, but pediatric massage had been flourished due to the particularity of its clinical needs. In 1604, the earliest surviving monograph in China: *Xiao Er Tui Na Fang Mai Huo Ying Mi Zhi Quan Shu (Secret Book of Children's Massage Prescription for Promoting Pulse and Saving Infants)* was published. This book was

written by Gong Ting-xian of Ming Dynasty. The book recorded new manipulations such as Gun-rolling, Da-beating and Pai-patting, Kai-opening and Tan-plucking, Na-grasping, etc., and mentioned the name of tuina for the first time. Since then, the children's tuina had gradually become a discipline, and the folks also changed the name of An Mo (massage) to tuina. After the founding of the People's Republic of China, Chinese medicine and massage therapy have received the attention of the government, and colleges and universities have opened specific education courses.

From the perspective of modern scientific theory, massage is a physical treatment, and it has certain physical parameters no matter which kind of manipulation it uses. Scholars at home and abroad have mainly focused on the relationship between the amount of stimulation and the location, force, direction and time of the manipulations. From then on, scholars have carried out a large number of clinical trials to study the mechanical parameters of the tuina manipulations. In the early 1980s, some scholars developed a sensory parameter acquisition device. The quantification of the manipulation parameters can guide the beginners to engage in the massage industry intuitively, helping them to master the essentials quickly. The doctor should be able to well understand a disease by observing the external manifestations and then treat it with manipulations.

## 2 The Objectification Study of the Technology of Tuina Manipulations

The study of physical parameters of massage manipulations mainly detects the relation between kinetic parameters (force and moment of force, momentum and moment of momentum, impulse and moment and work of impulse) and kinematic parameters under the premise of combining the volunteer's constitutional factors and his subjective and objective influencing factors. Kinematic parameters are divided into three aspects: time parameters (moment, time and frequency), spatial parameters (displacement, distance and angular displacement) and space-time parameters (speed, acceleration, angular velocity, etc)<sup>[7]</sup>. At home and abroad, parameters such as mathematical models, contact pressure sensors, displacement sensors, and photographic techniques were used for parameter measurement<sup>[8-11]</sup>.

### 2.1 Establishment of mathematical model to study the mechanism of tuina manipulations

The mathematical model of tuina manipulations mainly includes microcirculation model, hemodynamic model and finite element model<sup>[12]</sup>. At the end of the 20th century, some scholars used hemodynamic models to analyze the effect of blood flow parameters of blood vessels<sup>[13-14]</sup>, based on which, Xu SX, et al<sup>[15-17]</sup>

established a gradual stenosis radial oscillation hemodynamic model. Cheng WH, *et al*<sup>[18]</sup> numerically solved the linearized Navier-Stokes equations and studied the effects of different levels of permeability parameters, maximum stenosis and frequency of blood flow during Gun-rolling manipulation, which increased arterial blood flow and promoted blood circulation by multiple factors. Xu SX, *et al*<sup>[19]</sup> further studied the viscous flow in an axisymmetric rigid tube with narrow axial motion through an axially symmetric nonlinear model and an arbitrary Euler-Lagrangian finite element method using a narrow axial motion Gun-rolling manipulation, finding that the frequency can effect the blood flow and wall shear force. Bi S, *et al*<sup>[20]</sup> used ABAQUS6.1 finite element software to establish the finite element model of L<sub>4</sub>-L<sub>5</sub>, and observed the effects of different lumbar spine tuina manipulations on the internal structural changes of the lumbar spine.

At the beginning of the 21st century, Li HB<sup>[21]</sup> used the lattice Boltzmann method (LBM) to conduct a preliminary study of blood flow and explored the accurate calculation method of fluid interaction on the boundary. Lü XY<sup>[22]</sup> also used LBM to explore the features of blood flow in the elastic arteries of the blood flow system and the reaction of the blood vessel wall, based on which, Jin L, *et al*<sup>[23]</sup> used LBM to treat blood as an incompressible Newtonian fluid, established a sinusoidal Gun-rolling manipulation model, further studied the effects of tuina therapy on arterial flow, and explored the mechanism of tuina therapy for promoting blood circulation and removing blood stasis.

The mathematical model can simulate tuina manipulations and inner environment of body to some degree, which can produce considerable clinical value for studying the mechanism of massage therapy to reveal the effective pathway of the tuina manipulations in an objective way. After all, the model can't replace the real body environment during tuina treatment. The quantification of the tuina therapy itself is also a very important factor in the course of modeling. The combination of the model and quantification would truly explore the mystery of tuina manipulations.

## 2.2 Using video technology and three-dimensional (3D) motion analysis to study the physical parameters of tuina manipulations

In order to explore the regulation of the movement and dynamics of tuina manipulations, Zhang CQ<sup>[24]</sup> divided 30 therapists into a clinician group and a beginner group, collected data of 5 tuina manipulations (Gun-rolling, Dian-digital pressing, Rou-kneading, Pai-patting and Zhen-vibrating) of the therapists using digital cameras and computer 3D force gauges. The data were analyzed by the 3D mechanical analysis software using mechanical parameters such as force value, time, frequency, etc. The results showed that the 5 tuina manipulations were almost equal in force value and

frequency except the Rou-kneading manipulation. The coefficient of force and frequency variation in the clinician group was significantly lower than that in the beginner group, indicating that the clinicians' manipulations were relatively stable and durable.

Sun WQ, *et al*<sup>[25]</sup> believes that from the perspective of kinematics, the tuina manipulations are basically periodic motions, of which frequency is an important physical property. Different frequencies of the therapists may produce different therapeutic effects, indicating that the frequency is inversely related to the number of muscles and joints, the direction of force and the amplitude of the manipulations. Yan XH, *et al*<sup>[26-27]</sup> used 3D motion analysis system loading with Microsoft C# advanced programming language and data analysis software developed by MATLAB to analyze the perpendicular force and frequency of different types of manipulations and obtained specific parameters of frequency and force value: swinging vertical force <100 N, frequency at 110-260 times/min; rubbing vertical force <70 N, frequency at 70-130 times/min; extruding vertical force >200 N, frequency at 40 times/min; tapping vertical force <70 N, frequency at 50-280 times/min; vibrating vertical force <40 N, frequency >390 times/min. From the perspective of mechanics, the faster the frequency, the smaller the force value, and vice versa. That is the reason that different frequencies of tuina manipulations would produce different effects.

Some scholars have used photographic techniques to study the biomechanical parameters of tuina manipulations. Klein P, *et al*<sup>[28]</sup> used a 3D electronic measuring machine to perform 3D measurement of C<sub>3</sub>/C<sub>5</sub> vertebral body motion for 14 asymptomatic volunteers, and found that tuina manipulations on C<sub>3</sub>/C<sub>5</sub> vertebral body has an average axial rotation of 30°, a lateral bend of 46°, and a horizontal bend of 2°. Ngan JM, *et al*<sup>[29]</sup> measured the *in vivo* kinematic parameters of the neck rotation tuina manipulations of 8 volunteers treated by three therapists (including C<sub>5</sub>/C<sub>6</sub> axial-direction rotation, angular displacement of the head and lateral flexion angle) using a four-camera motion analysis system operating at 120 Hz, and found that there were certain differences in the kinematic parameters between different therapists.

Through real-time video technology shooting the tuina manipulations which would be processed by 3D motion analysis technology, we can perform 3D analysis for each therapist's manipulation, which helps us intuitively acknowledge the course and obtain the trajectory of the manipulations. However, the video technology is so far somewhat limited, and the shooting course may also have the disadvantages of incompleteness and inaccuracy, which will have certain impact on the later mechanical analysis. The video technology cannot directly reflect the spatial position

change of different parts of the therapist's hand during the operation of tuina manipulations.

### 2.3 Using mechanical sensor technology to study the mechanical parameters of tuina manipulations

In 1982, Shandong University of Traditional Chinese Medicine co-operated with Shandong Institute of Technology, and jointly developed the TDL-I type of dynamic force of tuina manipulations measuring device. This has been the first measuring instrument for tuina manipulations in China. It can be used to measure the force value in perpendicular and horizontal directions of mechanical parameters such as force magnitude and frequency<sup>[30]</sup>. Zeng QY<sup>[31]</sup> used TDZ-I type tuina force dynamic measuring device to compare and analyze the dynamic curve difference between Ding's classic Gun-rolling manipulation and that of ordinary tuina students, and analyze the causes of erroneous manipulations from the perspective of biomechanics.

Shandong University of Traditional Chinese Medicine has also successfully developed the TDZ-I type tuina manipulations dynamic measuring instrument. This instrument functions on basis of resistance chip and uses the sensor technology to successfully record the dynamic curves of tuina manipulations such as one-finger Tui-pushing, Gun-rolling, Zhen-vibrating, and Dian-digital pressing to obtain precious mechanical parameters including cycle, frequency, rhythm and intensity<sup>[32]</sup>. Kawchuk GN, *et al*<sup>[33-35]</sup> used contact pressure sensors to measure and record basic mechanical parameters such as the average thrust duration (ms), normalized average force peak (N), slope (N/ms) and force profile (graphic representation of the above values) of five commonly used tuina manipulations for cervical spine. Proposing that there was certain relation between the preload and force peak values in the practice of tuina on the spine. In 1996, Shanghai University of Traditional Chinese Medicine and the Department of Mechanics of Fudan University jointly developed the FZ-I type manipulation force measuring instrument. The FZ-I type allowed 3D analysis of the computer for real-time display, quantification and function of force on the basis of TDL type and TDZ type, which could serve for measuring and recording the geometric trajectory of the Gun-rolling manipulation. The geometric shapes of the 'heart' and 'calabash' were found to be the accurate trajectory of Gun-rolling manipulations<sup>[36]</sup>. The TPA-II tuina manipulation measuring instrument was developed by School of Acupuncture-moxibustion and Tuina, Shanghai University of Traditional Chinese Medicine. It can identify 3D force changes of the therapist in directions of up and down, left and right, and front and back, detect the tuina manipulations in a 3D manner, and fully discover the vector characteristics of the force.

Some scholars have developed the Engocheck general stress test system, which consists of an

inductive pressure pad, system cable, computer and monitor. The ABW main unit converts the pressure value into an electrical signal, and then uses the computer to convert the electrical signal into a force graphic. The system can monitor and record pressure changes in real time<sup>[37]</sup>.

At the beginning of the 21st century, Zhu LG, *et al*<sup>[38]</sup> and Feng MS<sup>[39]</sup> developed a rotary manipulator operating mechanics measuring instrument. A sensor was fixed to a pair of flexible sleeves, which was loaded by 3D accelerometer, pressure sensor and force plate to focus on force measurement during practice.

The development of sensor technology has vigorously promoted the parameter research of tuina manipulations. The pressure sensor and the system being equipped with sensors such as pressure and displacement, can measure the manipulations in a dynamic and contact way. For the record, the displacement sensor can only measure displacement, angle, time and speed, and the pressure sensor can only detect the pressure value, either of which is accurate and comprehensive. At present, some countries have made research on the new type of force-sensitive electrical rubber in piezoresistive properties and force information detection principle, proposing the idea of measuring the flexible contact pressure by taking the advantage of the piezoresistive properties of conductive rubber<sup>[40-44]</sup>. There is also a precedent for collecting tuina manipulation data using gloves with flexible sensors<sup>[45-48]</sup>. Hunan University of Chinese Medicine also designed a teaching and training system based on LabVIEW technology<sup>[49]</sup>. Therefore, improving the sensor acquisition technology is an urgent need for education and practice.

### 3 Summary

Mathematical models, video techniques combined with 3D mechanical analysis and mechanical sensors can help researchers quantify the mechanical parameters of tuina manipulations in certain aspects, but they all have defects, respectively. First, the mathematical model is a mathematical method that uses mathematical formulas, graphs, or specific algorithms to study the laws and characteristics of the target object. However, the mathematical model is always an idealized model beyond the computer terminal. It is impossible to control and simulate the influence of uncontrollable random factors in clinical practice which may produce some wrong conclusions. Secondly, video technology can perfectly capture the motion trajectory of objects and people. Combined with 3D motion analysis, it can analyze and record the force value, frequency, amplitude, time and motion trajectory, but the quality of the camera, the subjective factors (such as the angle of the shot, the accuracy and

objectivity of the target point), the processing of the post-production video, and the selection and operation of the analysis software will influence the final conclusion. Finally, mechanical sensors such as pressure and displacement ones can sense the manipulation trajectory, and obtain accurate mechanical data, such as displacement, frequency, angle and velocity. However, most of the sensors are large-volume rigid structures. In use, the sensor is fixed on the tuina plate, which makes the tuina therapists fail to consider the influence of illness features on manipulation parameter for each patient, thereby causing a certain error in the acquired data, which is not conducive to the development of quantitative research of tuina manipulations.

Tuina has been accepted by more and more people. However, it doesn't have a specific rule to standardize the practice of tuina manipulations. In order to promote the objective research of tuina parameters and the development of tuina, we should carry out the following tasks. First, we must improve the sensor to make it compact, flexible, precise and multi-range, thus ensuring high acquisition. Second, we must fully consider the personal condition of each patient, abandon the traditional large-scale manipulation tester, combine the miniaturized flexible sensor with elastic gloves, and develop a new type of data collection gloves. Third, improve the data acquisition module to ensure the fidelity of the original data conversion. Finally, actively cultivate computer talents with Chinese medical knowledge background, and draw on advanced mechanics analysis software and mathematical modeling equations to realize real-time, real 3D modeling, data analysis and store of tuina manipulations, to establish a national parameter database to guide the clinical practice and education assessment.

#### Conflict of Interest

There was no potential conflict of interest in this article.

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