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Motion video-based quantitative analysis of the 'lifting-thrusting' method: a comparison between teachers and students of acupuncture

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ABSTRACT

Objective To compare objective measures of needle manipulation between students and teachers of acupuncture using motion video analysis technology, to help support instructional acupuncture education.

Methods A total of 30 teachers and 60 students participated in this study. Acupuncture needles were inserted at LI11 and motion videos were recorded for three subtypes of 'lifting-thrusting' manipulation: (1) 'mild reinforcing-attenuating'; (2) 'reinforcing'; and (3) 'attenuating'. The videos were analysed using Simi Motion 3D software to acquire the movement parameters of four trace marks: 'thumb tip'; 'forefinger tip'; 'forefinger middle joint'; and 'forefinger base joint'. Differences between the two groups were compared using t-tests, X^2 tests and/or rank-sum tests.

Results Changes in the near-end interphalangeal joint were positively associated with a range of movement along the X axis. Motion parameters for the thumb tip, the proximal interphalangeal (PIP) joint of the forefinger and the X axis shaft swing near the end of the forefinger in the teacher group were higher than those in the student group. The teacher group featured smaller trough dispersion and smaller crest dispersion during 'reinforcing' and 'attenuating' manipulations, respectively.

Conclusions The 'lifting-thrusting' manipulation could be simplified as a fixed-axis rotation using metacarpophalangeal joints in the thumb and forefinger as the shaft centre. Teachers opened at a larger angular variation for the PIP during the lifting and thrusting processes with better spatial control. Temporal control was similar between groups and therefore appears easier to grasp. Repetitive training might be helpful for improving athletic and spatial stability during needle manipulation.

INTRODUCTION

As one of the basic operations in Traditional Chinese Medicine (TCM), acupuncture manipulation is considered to be an important factor[1] in the therapeutic effects of acupuncture treatment. Several studies have suggested the effect of acupuncture can vary based on different types of acupuncture manipulation, including changes in the frequency and amplitude of bioelectrical signals,[2 3] differential expression of genes and proteins,[4 5] and variable effects on the physical and chemical properties of the human body.[6–8] Therefore, analysing and summarising the key characteristics of acupuncture manipulation, using modern technologies, is an active area of research that may be critical in helping improve clinical efficacy.

Basic acupuncture manipulations can be divided into 'lifting-thrusting' and 'twisting' techniques, which refer to control of the up-and-down and rotational motion of the needle, respectively, using the fingers. More specifically, the 'lifting-thrusting' manipulation includes three subtypes: 'mild reinforcing-attenuating'; 'reinforcing'; and 'attenuating'. Quantitative analysis of acupuncture manipulation parameters has been available worldwide for a number of years. Data collection devices or techniques for measuring needle motion such as acupuncture manipulation parameter analysers,[9 10] motion tracking systems,[11] dynamic stress measurement systems,[12] and ultrasonography[13] have been applied in experimental and educational studies. Kinematic and kinetic parameters such as cycle, frequency and needle stress have also been developed. However, most of these data were not obtained in clinical circumstances because the acupuncture was performed using instruments instead

of the human body; such data on needle motion is arguably less relevant for acupuncture education than that based on finger motion.

The aim of this study was to examine for differences in quantitative measures of needle manipulation between students and teachers of acupuncture using motion video analysis technology that has been widely used in a variety of fields including sport[14] and sports injury rehabilitation processes.[15] Our intention was to analyse videos of finger joint motion using Simi Motion 3D software (http://www.simi.com) by acquiring kinematic parameters including velocity, acceleration and angle, while avoiding any interference with the operation of the practitioners during data collection; our ultimate objective was to improve and enhance the effectiveness of current acupuncture teaching methods.

METHODS

Participants

This study was approved by the ethics committee of Yueyang Hospital affiliated with Shanghai University of Traditional Chinese Medicine (reference no. 2016–108). Thirty teachers and 60 students (2010 and 2011) from the Acupuncture-Moxibustion and Tuina School of Shanghai University of Traditional Chinese Medicine were selected as the participants. All students finished the 'lifting-thrusting' chapter in the course textbook entitled 'Acupuncture and Moxibustion Techniques and Manipulations'[16] and had hands-on needling experience with the human body.

Experimental configuration

Before the experiment, an operating table was placed on a level floor. After adjusting the legs of a tripod to a specified length of 79 cm and setting it to the maximum angle, the tripod was placed on a specified location on the floor. A camera was connected to the well-positioned tripod and level adjustment was performed using the system's built-in levelling control within the camera, to ensure horizontal alignment of the lens. The distance from the centre of the lens to the floor was 84 cm and the vertical distance from the lens to the front edge of the experimental operating table was 33 cm. The camera and fill light were turned on. Camera parameters were set as follows: aperture F7.1; shutter velocity 1/1000 s; ISO 6400; auto white balance; optical zoom 33 mm.

Experimental methods

Video capture method
1. A small two-dimensional calibration frame was placed on the horizontal axis of the operating table vertically, for the 2D calibration operation of Simi Motion 3D version 7.5 (Simi Reality Motion Systems GmbH, Unterschleissheim, Germany).
2. All participants in the two groups were seated on the right side of the operating table and a volunteer was positioned on the other side to expose LI11 (*Quchi*),

located at the lateral end of the transverse cubital crease connecting LU5 with the lateral epicondyle of the humerus, on the right arm.
3. Four trace marks were labelled using thin markers on the right thumb and forefinger of all participants (figure 1A). The marks were located as follows: ulnar side of the thumb tip, with 0.1 inches superior to the nail root corner defined as 'thumb right' (TR); radial side of the forefinger tip, with 0.1 inches from the nail root corner, roughly the location of LI1 (*Shangyang*), defined as 'forefinger tip right' (FTR); radial side of the proximal interphalangeal joint (PIP) of the forefinger, with the dorso-ventral boundary of the joint defined as 'forefinger middle joint right' (FMJR); radial side of the metacarpophalangeal joint (MCP) of the forefinger, with the dorso-ventral boundary of the joint defined as 'forefinger base joint right' (FBJR).

A 0.30×50 mm disposable stainless steel acupuncture needle (Shenli Medical & Health Material Co, Ltd, Wujiang, China) was inserted at LI11 and used to test the following three 'lifting-thrusting' method subtypes: 'mild reinforcing-attenuating'; 'reinforcing'; and 'attenuating'; with video acquisition of the acupuncture manipulation.

Video processing

The same four 'trace marks' were established in Simi Motion 3D. Two connections (between FMJR and FBJR, and FTR and FMJ, respectively) were established accordingly. A 2D 3-point angle 'forefinger middle joint right angle' (FMJRA) was also formed by these two connections (figure 1B).

The 2D calibration frame was overlapped with the real video in Simi Motion and a rigid structure layout of the fingers was established automatically (figure 1C).

After conducting analysis with Simi Motion, the parameters for all the marks on each participant were acquired, including the coordinates of the X and Y axes and the velocities and acceleration along the X and Y axis. The 'angle parameters' for FMJRA included the angular degree, velocities and accelerations. Typical characteristic curves for the three subtypes of acupuncture manipulation 'lifting-thrusting', generated by Simi Motion, are shown in figure 2.

Statistical analysis

The motion amplitudes, average velocities and accelerations were calculated from the original data derived from Simi Motion. Based on the data of the TR coordinate curve of the Y axis, the average time course for lifting (T_1) and thrusting (T_2), average coordinate value of the crests and troughs, dispersion (standard deviation) of T_1, T_2, as well as the crests and troughs were also calculated to compare the stability of the manipulation. All outcomes were compared between the two groups with t-tests, X^2 tests and/ or rank-sum tests using the Statistical Package for the Social Sciences (SPSS) version 19.0 (SPSS Inc, Chicago, IL, USA).
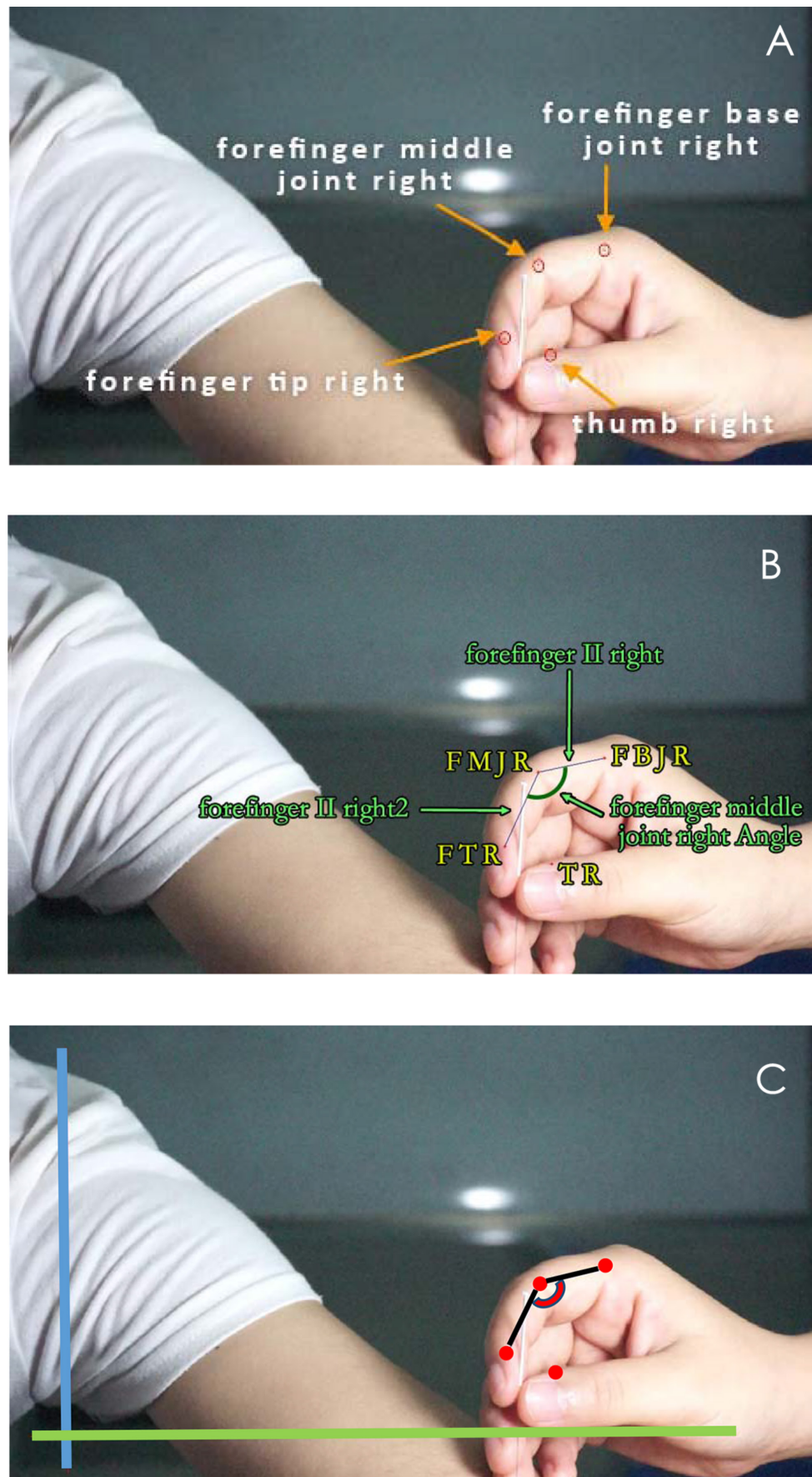
Figure 1 Summary of finger trace marks and settings of Simi Motion 3D during acupuncture manipulation. (A) Illustration of finger trace marks. (B) Illustration of the Simi Motion points, connections and angle. (C) Illustration of 2D calibration overlapping, trace marks and connections.
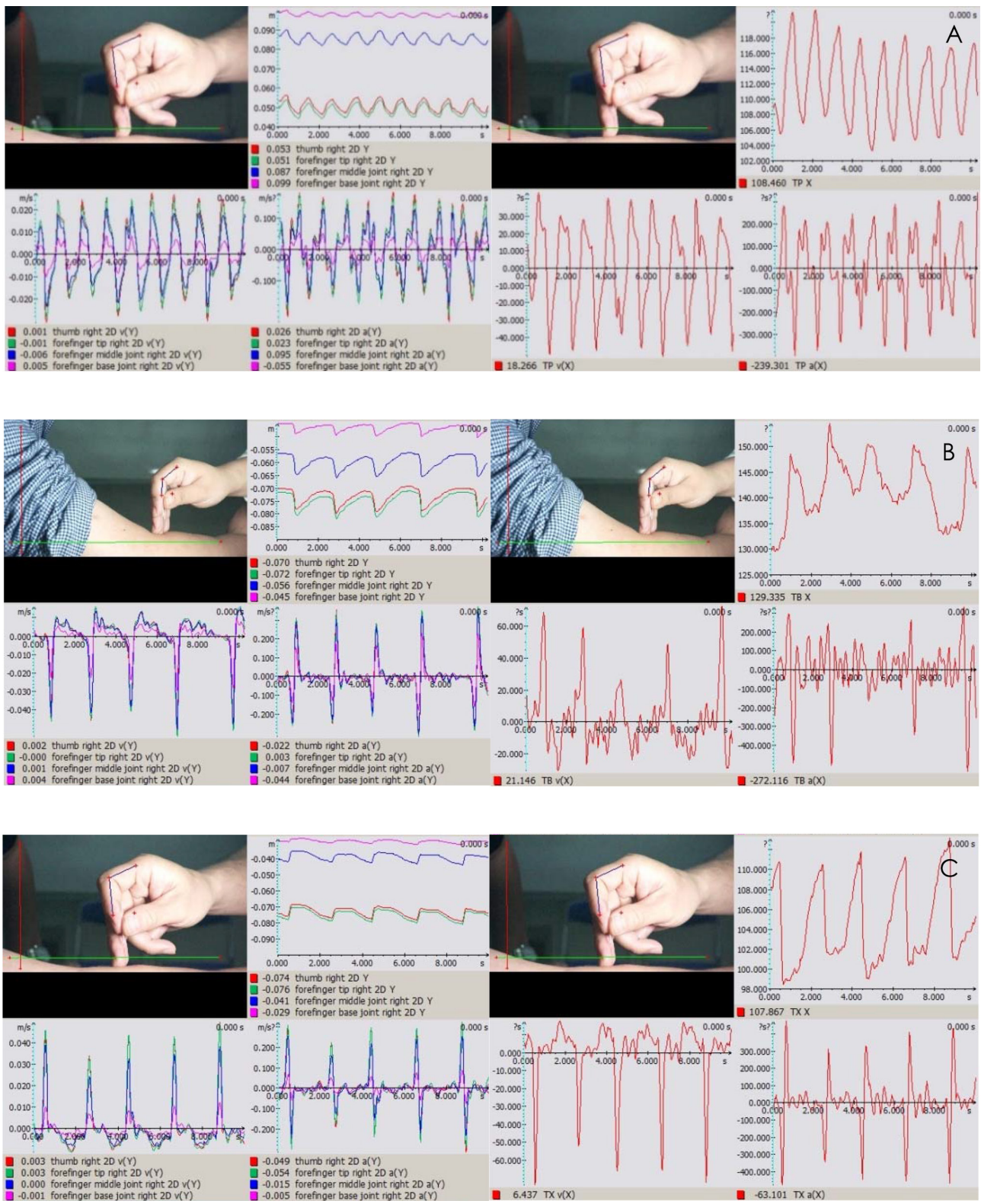
Figure 2 Typical curves of motion parameter and angle parameters for the 'lifting-thrusting' method of acupuncture manipulation. Panels A, B and C illustrate the curves of the motion and angle parameters for the 'mild reinforcing-attenuating', 'reinforcing', and 'attenuating' subtypes of acupuncture manipulation, respectively. Within each panel, left and right curves show motion and angle parameters, respectively. The upper left region represents the original video. Other sections of the motion parameter curves include coordinates (upper right), velocity (lower left) and acceleration (lower right) along the Y axis for all marks. Other sections of the angle parameter curves include angular degree (upper right), angular velocity (lower left) and angular acceleration (lower right) for 'forefinger middle joint right angle' (FMJRA).

RESULTS

Due to inherent bias in participant inclusion in keeping with the experimental design, there was a statistically significant age difference between the two groups (22.9 ± 0.81 vs. 39.7 ± 5.69 years for students and teachers, respectively; $p<0.01$ by t-test), but no significant gender difference at baseline (male:female ratio 20:40 in student group and 16:14 in teacher group; $p>0.05$ by X^2 test). Comparisons of motion parameters and manipulation cycles/dispersions between the two groups are presented in tables 1 and 2, respectively.

Mild reinforcing-attenuating method

As shown in the 'mild reinforcing-attenuating' section of table 1, relative to the students, the teachers showed greater amplitudes, velocities and accelerations along the X axis for all marks and additionally on the Y axis for TR. Similar to the above results, greater angular variation, velocity and acceleration of FMJRA were also evident in the teacher group. A longer duration of T_2 was found in the student group, according to the corresponding results in table 2, which suggests all of the participants had similar temporal and spatial control.

Reinforcing method

Looking at the 'reinforcing' sections of tables 1 and 2, the teachers showed greater amplitudes along the X axis for TR, FTR, FMJR and Y axis for TR. Greater velocities along the X axis for FMJR and Y axis for TR, together with great acceleration along the X axis for TR, were also exhibited in the teacher group. Similar to the results of the 'mild reinforcing-attenuating' method, teachers showed greater angular parameters of FMJRA. In terms of the manipulation cycles and dispersions, teachers showed smaller trough dispersion, which implies that the student group was inferior to the teacher group with respect to depth control during the 'reinforcing' type of manipulation.

Attenuating method

As demonstrated in the 'attenuating' section of tables 1 and 2, the teachers showed greater amplitudes along the X axis for all marks as well as the Y axis for TR. Teachers' manipulations were also characterised by greater velocities along the X axis for FTR and FMJR, and larger acceleration along the X axis for all marks. Equivalent results in terms of angular parameters compared with the other methods were found when analysing the 'attenuating' method. In terms of manipulation cycles and dispersions, teachers showed smaller crest dispersion, implying that the student group was inferior to the teacher group with respect to lifting amplitude control during the 'attenuating' type of manipulation.

DISCUSSION

Overall characteristics

From the above results, it is apparent the manipulation parameter data mainly followed an atypical distribution featuring a large standard deviation. Although there are detailed provisions for the cycle, frequency and amplitude parameters found in the 'Acupuncture and Moxibustion Techniques and Manipulations' textbook,[16] quantitative results were diverse with significant differences in amplitude and frequency between individuals. These results were also consistent with previous studies by Yi et al[17–19] and Davis et al.[20]

Participants in both groups showed good control with respecrt to temporal parameters. T_1 and T_2 were relatively similar for 'mild reinforcing-attenuating' manipulations, and T_1 was larger than T_2 during the 'reinforcing' technique. By contrast, T_2 was larger than T_1 using the 'attenuating' method. These differential performances demonstrate the technical characteristics of different needling manipulations; similar temporal features were also reported in the work of Yi et al.[17]

Another common characteristic of the 'lifting-thrusting' method is the symmetry of motion. In this study, measurements were located in the 2D plane of the X and Y axes and the 'lifting-thrusting' manipulation was mainly an up-and-down motion along the Y axis. Therefore, motion amplitudes along the Y axis were larger, often >1 cm. At all trace marks, motion amplitudes, velocities, and accelerations for TR and FTR were quite similar, likely because of the proximity of these two marks. The parameters of FMJR and FBJR were quite small and FBJR was smallest of all. TR, FTR and FMJR presented left-and-right movements along the X axis, with smaller motion amplitudes, velocities, and accelerations compared with those along the Y axis. Also, there was an increasing tendency for TR to move towards FTR and towards FMJR. In the opposite direction to the other marks, results on the X and Y axes for FBJR were very close. It could be summarised that the 'lifting-thrusting' manipulation represents a fixed-axis rotation with the metacarpophalangeal joint of the thumb and forefinger constituting the axis. During such motion, the difference in length between the thumb and forefinger, and the position of the needle between these two digits, forces FMJRA to an approximate value of 120–140° with rhythmic increase and reduction. Due to the generation of this angle, motion along the X axis increased for all marks.

Group comparisons

Key differences between the two groups included variance of motion amplitude, velocity and acceleration along the X axis for the three subtypes, especially for TR and FTR. According to differences in angular degree, velocities and accelerations of the FMJRA, it was observed that the left-and-right amplitudes were larger in the teacher group. Therefore, apart from

Table 1 Comparison of motion parameters for 'lifting-thrusting' method

Parameter type	Parameter	Mild reinforcing-attenuating		Reinforcing		Attenuating	
		Students (n=60)	Teachers (n=30)	Students (n=60)	Teachers (n=30)	Students (n=60)	Teachers (n=30)
Average motion amplitude	TR-X(cm)	0.453±0.192**	0.598±0.261	0.432±0.156**	0.58±0.196	0.469±0.195*	0.575±0.238
	TR-Y(cm)	1.186±0.387	1.283±0.530	1.189±0.435**	1.482±0.576	1.623±0.363**	1.398±0.541
	FTR-X(cm)	0.523±0.0229*	0.722±0.325	0.496±0.197**	0.689±0.263	0.546±0.267*	0.671±0.281
	FTR-Y(cm)	1.162±0.415	1.144±0.421	1.188±0.512	1.215±0.427	1.15±0.429	1.267±0.497
	FMJR-X(cm)	0.673±0.355*	0.959±0.374	0.664±0.279*	0.936±0.346	0.669±0.366*	0.881±0.299
	FMJR-Y(cm)	1.001±0.354	1.023±0.375	1.032±0.456	1.118±0.433	0.981±0.412	1.164±0.534
	FBJR-X(cm)	0.479±0.206*	0.586±0.285	0.43±0.141	0.486±0.25	0.471±0.225	0.479±0.147
	FBJR-Y(cm)	0.515±0.208	0.557±0.405	0.55±0.247	0.654±0.345	0.5±0.194	0.607±0.497
	FMJRA(rad)†	18.87±10.148**	27.225±11.066	19.876±9.617*	29.546±11.371	20.994±11.99**	27.6±10.238
Average motion velocity and angular velocity	TR-X(cm/s)	0.318±0.186**	0.586±0.501	0.275±0.123	0.377±0.161	0.309±0.198	0.373±0.195
	TR-Y(cm/s)	1.260±0.679**	1.619±0.873	0.946±0.398	1.068±0.25	0.907±0.332	1.013±0.386
	FTR-X(cm/s)	0.396±0.249*	0.77±0.593	0.348±0.187	0.452±0.25	0.365±0.221*	0.472±0.247
	FTR-Y(cm/s)	1.273±0.769	1.445±0.782	0.95±0.487	1.272±1.839	0.896±0.388	0.95±0.363
	FMJR-X(cm/s)	0.504±0.32**	1.022±0.59	0.471±0.253*	0.665±0.385	0.46±0.353*	0.642±0.356
	FMJR-Y(cm/s)	1.067±0.601	1.304±0.689	0.805±0.396	0.795±0.289	0.754±0.37	0.853±0.357
	FBJR-X(cm/s)	0.273±0.133*	0.4±0.228	0.28±0.167	0.278±0.137	0.268±0.238	0.281±0.136
	FBJR-Y(cm/s)	0.525±0.328	0.611±0.662	0.414±0.213	0.368±0.172	0.334±0.152	0.364±0.258
	FMJRA(rad/s)‡	18.015±11.544*	30.175±14.961	14.966±8.206*	21.542±10.871	16.888±10.632*	21.806±10.669
Average motion acceleration and angular acceleration	TR-X(cm/s²)	2.378±1.609**	5±5.395	2.057±0.926*	2.279±1.127	2.403±1.865*	2.939±1.475
	TR-Y(cm/s²)	7.665±5.497**	11.783±9.923	6.021±2.592*	6.928±2.373	5.852±2.563	6.648±2.629
	FTR-X(cm/s²)	2.747±1.799*	6.347±6.281	2.607±1.346	3.304±1.667	2.724±1.733**	3.569±1.867
	FTR-Y(cm/s²)	7.653±6.029	10.612±9.678	6.026±2.927	6.069±1.809	5.915±2.778	6.426±2.662
	FMJR-X(cm/s²)	3.29±2.083*	7.362±5.492	3.351±1.908	4.242±2.395	3.43±3.173*	4.62±2.57
	FMJR-Y(cm/s²)	6.452±4.595	9.386±8.156	5.232±2.429	5.329±1.657	4.963±2.534	5.649±2.436
	FBJR-X(cm/s²)	1.983±1.1*	3.022±1.818	2.231±1.721	2.094±0.825	2.17±2.46*	2.639±1.855
	FBJR-Y(cm/s²)	3.392±2.572	4.803±7.004	2.921±1.521	2.596±1.005	2.345±1.116	2.639±1.855
	FMJRA(rad/s²)§	110.6±64**	204.6±130	103.8±51.2*	141.4±72.5	120.5±68.1*	153.6±72.5

*p<0.05; **p<0.01.
†Angular degree.
‡Angular velocity.
§Angular acceleration.
FBJR, forefinger base joint right; FMJR, forefinger middle joint right; FTR, forefinger tip right; TR, thumb right.

Table 2 Comparison of manipulation cycles and dispersions for 'lifting-thrusting' method

	Mild reinforcing-attenuating		Reinforcing		Attenuating	
	Students (n=60)	Teachers (n=30)	Students (n=60)	Teachers (n=30)	Students (n=60)	Teachers (n=30)
T_1(s)	0.704±0.442	0.567±0.218	1.449±0.512	1.478±0.498	0.584±0.337	0.472±0.221
T_2(s)	0.798±0.411*	0.612±0.245	0.786±0.428	0.718±0.289	1.382±0.513	1.278±0.387
T_1 dispersions	0.115±0.103	0.107±0.066	0.218±0.135	0.298±0.144	0.158±0.118	0.127±0.119
T_2 dispersions	0.129±0.114	0.083±0.036	0.176±0.137	0.177±0.085	0.282±0.319	0.267±0.206
Curve crest dispersions	0.005±0.002	0.005±0.003	0.0062±0.0033	0.0067±0.0047	0.0027±0.0016*	0.0011±0.0006
Curve trough dispersions	0.003±0.002	0.004±0.003	0.003±0.0028*	0.0017±0.0009	0.0067±0.0048	0.0076±0.0041

All the manipulation cycles and dispersions were based on the data of the 'thumb right' (TR) coordinate curve of the Y axis.
*p<0.05; **p<0.01.

one parameter along the Y axis, the teacher group demonstrated consistently larger amplitudes along the X axis compared to the student group. We hypothesise that participants in the teacher group may have expanded the motion amplitude gradually over time after extensive clinical and educational practice. On the Y axis, the main difference between the two groups was the motion amplitude of TR. Differences were also found in velocity and acceleration along the Y axis with the exception of the 'attenuating' manipulation. The results also showed the teacher group generally demonstrated higher amplitudes, velocities and accelerations than the student group. In summary, the teacher group exhibited: (1) higher motion parameters for TR; (2) larger FMJRA; and (3) higher axial swinging amplitude along the X axis.

The finger movements of basic acupuncture manipulations are considered to represent typical rhythmic motions, and their control can be divided into two parts: temporal and spatial. In the 'lifting-thrusting' method, T_1 and T_2 represent temporal control, the crest and trough represent spatial control, and their dispersions represent the stability of the manipulation. The parameters associated with temporal control and its stability were quite similar between the two groups except for the T_2 dispersion, which suggested similar temporal control abilities across both groups. In terms of spatial control and its stability, the results showed that the teacher group had better trough dispersion during the 'reinforcing' manipulation, and better crest dispersion when 'attenuating'; this indicated that, in the process of rapid finger movement, the ability of the teacher group to grasp the rhythmical spatial position was better than that of the students.

The characteristics of temporal and spatial movement are often seen as being controlled separately, although they are not independent.[21] According to the actual teaching situation in the classroom, the learning of acupuncture manipulation techniques could be regarded as a type of action observation (AO). A previous study revealed that spontaneous movement tempo can be influenced immediately following AO, which was reflected in the synchronous rhythms.[22]

However, compared with physical practice, AO is weaker in the reproduction of motor coordinates for simple rapid movement sequences.[23] Therefore, it may be easier to acquire temporal control ability with AO, while the spatial control ability relies on practice. Therefore, due to the differing amount of experience between students and teachers, it is perhaps unsurprising that the spatial control ability of teachers appeared to be better than students.

Based on the findings of our study, we would tentatively make some recommendations for teaching of the 'lifting-thrusting' method of acupuncture. First, the technology of motion video-based quantitative analysis may be useful for the evaluation of student manipulation. Second, a focus on guiding students to increase the motion amplitudes along the X axis by training them to appropriately flex their PIP is advised. Finally, we suspect that students may be able to improve their spatial control ability by peforming repetitive exercises in their spare time.

Conclusion

Acupuncture manipulation parameters followed an atypical distribution with a large standard deviation and multiple features. A rhythmic double-shaft movement of the thumb and forefinger for the operator was evident. The 'lifting-thrusting' manipulation can be simplified as a fixed-axis rotation, taking the metacarpophalangeal joints of the thumb and forefinger as the shaft centre. The teacher group subtended a larger angle with the finger joints during needling. The teacher group also showed better spatial control, while temporal control was similar between groups and therefore appears easier to grasp. Repetitive training may be helpful to improve the athletic and spatial stability of manipulation.

Future work

Based on the present results, we recommend that further experiments should be designed to evaluate improvements in students' skills with the help of motion video analysis. Application of this approach to other types of acupuncture manipulation, such as

'twisting-rotating', could help improve other parameters for instructional purposes. Ultimately, this study is only the first step in quantitative comparison of acupuncture manipulations using motion video analysis technology.[19] More parameters may be compared with infrared motion capture technology using a 3D coordinate system.[24] We believe these techniques could make acupuncture education more effective, by facilitating quantitative research into different types of acupuncture manipulation.

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