Perceptual motor features of expert acupuncture lifting-thrusting skills

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ABSTRACT

Background Little is known with regard to how acupuncture skills are optimally taught, learnt and evaluated despite clear evidence that technical skill acquisition is important to trainee success in health professions.

Objectives This study reports an investigation of the sensorimotor aspects of the acupuncture lifting-thrusting skill in order to highlight the important kinematic and kinetic features of the action. The study also explores the role of perceptual acuity in accurate acupuncture performance.

Methods Twelve novice and 12 expert acupuncturists watched a standardised video demonstrating the mild reinforcing and reducing technique of lifting-thrusting on an acupuncture point and then performed 10 trials of the technique on an artificial skin pad mounted on a six-axis force transducer with an infrared light-emitting diode affixed to the index finger of their dominant hand. The force transducer measured the force applied by participants as they Needled the acupuncture point while an optoelectric camera measured the position of the diode. Subsequently, the participants engaged in two tests of general perceptual acuity.

Results Repeated measures analyses of variance indicated that experts are more consistent in their trial-by-trial amplitude (p=0.03) and lifting-thrusting velocity (p=0.029) than novices. Measures of perceptual acuity revealed no differences between novices and experts.

Conclusions Movement amplitude and velocity consistency are the action features of the mild reinforcing and reducing lifting-thrusting skill that differentiate the performances of experts from novices. The acquisition of acupuncture expertise is a function of extended practice rather than any inherent perceptual ability.

INTRODUCTION

Acupuncture treatment purports to stimulate the body through the activation of regulatory functions that improve and rectify physical disturbance and dysfunction. It is used effectively for disease treatment and health maintenance all over the world.1 However, incompetent acupuncture performance can result in needle pain, haematoma and bent or broken needles that may have an unfavourable impact on therapeutic effects.1 Yet, little emphasis has been put on quantifying the aspects of motor control that are relevant to the training and evaluation of acupuncture skills. Traditionally, the most common acupuncture pedagogy involves a strategy in which teachers describe and demonstrate skills for students who train on soft pads for long periods before practising on one another. The skill competence of trainees is usually evaluated by the subjective, and potentially inaccurate, evaluations of observing examiners.2 There is, for instance, rarely much attention paid to students’ accuracy in force control.

To date, the research into quantitative objective methods of training and assessment of acupuncture skills is limited. Over the last decade, Gu,3 Ding et al4 and Yang et al5 affixed piezoelectric transducers in needle handles to monitor the generation of real-time thrust forces. More recently, Liu et al6 used motion sensors to capture the real-time position of needles during acupuncture manipulation. This latter work resulted in the development of the ‘Acupuncture Manipulation Information Analysis System’, which uses recorded performances of needle insertions to help teachers assess objectively the skill level of students.7 Importantly, although this work was successful in highlighting quantifiable features of the performance of expert acupuncturists,4 8–10 none of these studies reported on the accuracy of the instruments employed and the omission of a novice control group across the studies represents a barrier to establishing the construct validity of the developed technology. A recent comparison by Davis and colleagues of the...
performance by experts of two needling techniques showed a large variation between practitioners but no major differences in force production between the techniques.11

In the present study we have used advanced motion capture systems to measure the force, amplitude, frequency and velocity of the lifting and thrusting components of acupuncture. Lifting-thrusting is one of the basic acupuncture techniques. It involves inserting a filiform needle into an acupuncture point to a certain depth and then lifting and thrusting the needle perpendicularly and continuously until the arrival of qi. Qi is regarded as a kind of energy, and when qi arrives, acupuncturists feel a subtle sense of heaviness and tension beneath the needles.1 12 This skill is simultaneously complicated and flexible. The force, amplitude and frequency of thrusts, as well as the velocity of lifting and thrusting, depend on the location of the acupuncture point and also on the patient’s constitution and pathological condition. There are three popular lifting-thrusting techniques: (1) the reinforcing method with a smaller thrust force, amplitude and frequency and faster thrusting; (2) the reducing method with a larger thrust force, amplitude and frequency and faster lifting; and (3) the mild reinforcing and reducing method with a moderate thrust force, amplitude and frequency and relatively equal lifting and thrusting velocities.1

This work improves on previous efforts by including comparisons of the lifting-thrusting performance of both expert and novice acupuncturists in the mild reinforcing and reducing technique. These comparisons will highlight the action features of lifting-thrusting skills that are unique to experts and, in turn, promote the development of objective and quantitative performance standards. Specifically, we anticipate that the performance of experts in the mild reinforcing and reducing method will be characterised by more consistent movements and force production than that of novices. Furthermore, in addition to seeking the unique motor features of expert acupuncture needling, we also aim for a better understanding of the role of general sensory perceptual ability in acupuncture expertise. To this end, participants were asked to undergo tests of general sensory perceptual acuity on their fingertips. We anticipate that these measures of cutaneous sensation will not differ between experts and novices.

MATERIALS AND METHODS

Participants

The study participants were 12 novice acupuncturists (six men, six women, mean age 25 years) and 12 expert acupuncturists (six men, six women, mean age 36 years). The novices were members of the University of Toronto community with no prior experience of inserting an acupuncture needle. The experts were individuals who had performed a minimum of 350 h of clinical acupuncture practice and included acupuncture practitioners, students in their final year of acupuncture training (beyond the minimum amount of practice required to be considered qualified for independent practice) and recent graduates from the Toronto School of Traditional Chinese Medicine (Toronto; n=10) and the Shiatsu School of Canada Acupuncture Institute (Toronto; n=2). All members of this group were legally allowed to practise acupuncture independently. All participants provided informed consent according to the guidelines set out by the Declaration of Helsinki (1954) and the University of Toronto Research Ethics Board.

Protocol

The participants watched a video demonstrating a standardised technique for performing mild reinforcing and reducing lifting-thrusting on an acupuncture point. The technique demonstrates the application of moderate thrust force, amplitude and frequency as well as relatively equal velocities in lifting and thrusting. Following the video demonstration, the participants performed 10 trials of the procedure using professional needles (0.25 mm in diameter and 40 mm in length; Ecu, Maanshan Bond Medical Instruments, China) on a simulated skin pad (Professional Skin Pad Mk 2, Limbs & Things Ltd, UK). Participants were provided with a standardised clinically relevant scenario to contextualise their performance. This scenario indicated that the participant was to perform the procedure with six lifts and thrusts that were gentle in force and consistent in amplitude, frequency and velocity. Each trial included sterilisation, initial needle insertion, acquisition of desired needle depth, six needle lifts and thrusts and needle withdrawal. The simulated skin pad was mounted on top of a six-axis N/T force transducer (ATI Industrial Automation, USA) which measured (within 0.000001 N) the real-time force applied by the participant along the axis of thrust application. The transducer outputs provided information regarding the time period between initial needle insertion and acquisition of the desired needle depth that occurs just before lifting-thrusting is initiated (T1), the total time between initial needle insertion and the end of the sixth lift-thrust (T2) and the time spent on the six lift-thrusts (T3) (figure 1). Using deductive means, thrust frequency was calculated from T3.

Simultaneously, an optoelectric camera (Optotrak 3020, Northern Digital, Waterloo, Canada) with high spatiotemporal resolution and accuracy (0.01 mm and 0.1 mm, respectively) captured the real-time displacement (mm) of an infrared light-emitting diode affixed to the fingernail of the index finger of the participant’s dominant hand. Thrust amplitude (mm), time associated with each lift (lifting time, ms) and time associated with each thrust (thrusting time, ms) were recorded (figure 2). The ratio of lifting time to thrusting time (L/T) was calculated to differentiate between reinforcing, reducing or mild reinforcing and reducing.
methods. The L/T of the reinforcing method is much more than 1 while the L/T of the reducing method is much less than 1. An L/T of 1 is optimal for the mild reinforcing and reducing method.

After completing the 10 acupuncture trials, the participants undertook two tests of general sensory perceptual acuity: the von Frey hair test and the two-point discrimination test. Both tests were carried out on the tips of the index finger, middle finger and thumb of both hands. The von Frey hair test uses a series of monofilaments (Touch-Test Sensory Evaluators, North Coast Medical, California, USA) to establish an individual’s cutaneous sensation threshold. The participant’s vision is occluded while the smallest filament is pressed against the skin of the fingertips at an angle of 90° until it bows. The participant is asked to respond when s/he feels the filament. If s/he does not respond, a larger filament is chosen and the process is repeated. The size of the filament to which the participant first responds is recorded as the measure of the cutaneous sensation threshold. The two-point discrimination test involves the use of aesthesiometers (#16011, Lafayette Instruments, Lafayette, Indiana, USA). The two points of the aesthesiometer, arranged close together, are touched to the skin of the fingertips simultaneously. Without the aid of vision, the participant reports whether s/he feels one or two points. The separation of the points is gradually increased until the individual reports the perception of two points. The distance separating the two points is read from the aesthesiometer and provides an accurate measure of the individual’s two-point discrimination threshold.

**Statistical analysis**

The mean and SD of the thrust force, amplitude and L/T were calculated across the six lift-thrusts performed in each trial. Thus, for each participant, 10...
means and SDs of force, amplitude and L/T were obtained. The means and SDs for each dependent variable were analysed independently in the two groups (experts and novices) by 10 trial repeated measures analyses of variance (ANOVA). As a lower SD score is an indicator of less trial-to-trial variability, the analysis of SD represents another comparison of the relative consistency between the groups. Similar repeated measures ANOVA were conducted on T1, T2 and frequency data. The outcomes associated with the tests of general perceptual acuity were analysed for differences between the two groups in independent t tests. Tukey’s HSD post hoc method was used to decompose any ANOVA effects significant at <0.05.

RESULTS

There were no group or trial differences in the magnitude or consistency of the thrust force (grand mean=0.26 N; grand SD=0.05 N).

Analysis of the thrust amplitude showed no group or trial differences (grand mean=10.1 mm). However, the analysis revealed a significant group difference in the SDs of the thrust amplitudes produced (F(1, 21)=5.138, p=0.03). Post hoc analysis of this effect indicated that novices (SD=2.1 mm) produced more variable thrust amplitudes than experts (SD=1.58 mm). Similarly, the SD of L/T in expert group, 0.32, is significantly smaller than that of novice group, 0.44, p=0.029. The mean L/T in the expert group was 1.14, which was nearer to 1 than that of the novices (1.22), although no difference between the two groups was found.

Analysis of the thrust frequency showed no group or trial differences (grand mean=57.8/min). There were also no statistically significant differences in the analysis of the SD of thrust frequency (grand mean=7.9/min).

The analysis of T1 revealed significant group and trial main effects (F(1, 22)=24.59, p<0.001; F(9, 22)=5.83, p<0.001, respectively). Post hoc analysis of the group main effect indicated that novices take significantly longer preparing to lift-and-thrust than experts. Post hoc analysis of the trial main effect indicated that lifting and thrusting was initiated a shorter period of time after needle insertion on the tenth trial than on the first trial (figure 3).

No significant difference in T2 was found between the groups although novices showed a tendency to take longer than experts (grand mean=20.32 s). However, the analysis of T2 revealed a significant trial main effect (F(9, 22)=2.89, p=0.041). Post hoc decomposition of the effect indicated that lifting and thrusting was initiated a shorter period of time after needle insertion on the tenth trial than on the first trial.

The tests of general perceptual acuity showed no group differences. Specifically, analysis of the von Frey

Table 1 von Frey hair test outcomes (g)

<table>
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<tr>
<th>Dominant hand</th>
<th>Non-dominant hand</th>
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<tbody>
<tr>
<td></td>
<td>Thumb</td>
</tr>
<tr>
<td>Experts</td>
<td>0.61±0.17</td>
</tr>
<tr>
<td>Novices</td>
<td>0.70±0.00</td>
</tr>
<tr>
<td></td>
<td>0.66±0.14</td>
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<td></td>
<td>0.66±0.14</td>
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hair test (table 1) and the two-point discrimination test (table 2) outcomes revealed no differences between experts and novices. For the von Frey hair test the grand mean was 0.064 g and, for the two-point discrimination test, the grand mean was 2.69 mm.

**DISCUSSION**

This study has identified a motor feature of lifting-thrusting that differentiates expert performance in the mild reinforcing and reducing technique from novice performance—namely, the consistency of the movements. The significantly smaller SDs of thrust amplitude and lifting-thrusting velocity in the expert group indicate that the experts perform the skill component with less trial-to-trial variability movements than those of novices. It is noteworthy, however, that each expert performed the lifting-thrusting with different forces, amplitudes and frequencies—that is, there was no standard exhibited for lift-thrust force, amplitude or frequency. These findings are consistent with the outcomes of previous studies.8–11 Thus, quantification of needling variability may be a useful measure for developing objective assessments of the lifting-thrusting skill.

There was also a temporal feature of the lifting-thrusting skill that differentiated experts and novices. Our study showed that experts spend less time inserting the needle into the skin and acquiring the desired depth before initiating lifting-thrusting. In this regard, temporal efficiency appears to be a critical feature of expert acupuncture skill.

Perhaps the most interesting finding is the lack of any difference between experts and novices with respect to general perceptual acuity. This strongly suggests that the acquisition of expertise in the lifting-thrusting skill depends primarily upon practice and not on inherent perceptual acuity. This is particularly interesting when one considers that students are regularly taught that a critical aspect of the delivery of acupuncture therapy is the practitioner’s ability to judge the arrival of qi, or the fine sense of heaviness and tension beneath the needle. If the ability to perceive the arrival of qi is not an inherent ability, then we must assume that it is also derived from a large amount of practical experience. Further work is needed to investigate the specific sensory features associated with the arrival of qi and the processes by which acupuncture trainees come to perceive these features.

<table>
<thead>
<tr>
<th>Dominant hand</th>
<th>Non-dominant hand</th>
</tr>
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<tbody>
<tr>
<td>Thumb</td>
<td>Index finger</td>
</tr>
<tr>
<td>Experts</td>
<td>2.83±0.39</td>
</tr>
<tr>
<td>Novices</td>
<td>2.92±1.00</td>
</tr>
<tr>
<td>Thumb</td>
<td>3.00±0.60</td>
</tr>
<tr>
<td>Index finger</td>
<td>2.92±1.16</td>
</tr>
<tr>
<td>Middle finger</td>
<td></td>
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**Summary points**

- Little is known about skill of needle manipulation.
- We found experts make more consistent movements than novices.

**Contributors**  
JL designed and performed the experiments, analysed the data and wrote the manuscript. LEMG contributed to the experimental design of the research, data collection and the generation of the manuscript. MXW and RB contributed to the experimental design of the research and the generation of the manuscript. HC planned and supervised all features of the projects. All authors contributed to the critical revision of the paper and approved the final manuscript for publication.

**Funding**  
JL is supported by the Fund of Jiangsu Education Bureau (11KJB360001) and the Project Funded by the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), China. MXW is supported by the Research Fund of the Toronto School of Traditional Chinese Medicine. HC is supported by the BMO Chair in Health Professions Education Research.
Competing interests None.

Ethics approval Research Ethics Board Manager, Health Sciences, University of Toronto.

Provenance and peer review Not commissioned; externally peer reviewed.

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*Acupunct Med* 2013 31: 172-177 originally published online February 1, 2013
doi: 10.1136/acupmed-2012-010265

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