

# A new method for quantifying the needling component of acupuncture treatments

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## ABSTRACT

**Objectives** The highly variable nature of acupuncture needling creates challenges to systematic research. The goal of this study was to test the feasibility of quantifying acupuncture needle manipulation using motion and force measurements. It was hypothesised that distinct needling styles and techniques would produce different needle motion and force patterns that could be quantified and differentiated from each other.

**Methods** A new needling sensor tool (Acusensor) was used to record needling in real time as performed by six New England School of Acupuncture staff from the 'Chinese acupuncture' (style 1) and 'Japanese acupuncture' (style 2) programmes (three from each). Each faculty expert needled 12 points (6 bilateral locations) in 12 healthy human subjects using tonification (technique 1) and dispersal (technique 2). Parameters calculated from the raw needling data were displacement amplitude, displacement frequency, rotation amplitude, rotation frequency, force amplitude and torque amplitude.

**Results** Data analysis revealed significant differences in the amplitude of displacement and rotation between needling performed by staff from two different acupuncture styles. Significant overall differences in the frequency of displacement between techniques 1 and 2 that were not dependent of the style of acupuncture being performed were also found. The relationships between displacement and rotation frequencies, as well as between displacement and force amplitudes showed considerable variability across individual acupuncturists and subjects.

**Conclusions** Needling motion and force parameters can be quantified in a treatment-like setting. Needling data can subsequently be analysed, providing an objective method for characterising needling in basic and clinical acupuncture research.

## INTRODUCTION

Acupuncture needle manipulation is one of the most fundamental yet widely variable components of acupuncture treatments. Needles may be rotated in one or both directions or pistoned up and down in a myriad of combinations. These techniques may range from subtle and barely perceptible to vigorous, rapid and forceful.<sup>1-6</sup>

Factors that determine the amplitude, frequency and forcefulness of manipulation are numerous, including, but not limited to, the style of acupuncture being performed and the type of technique that is used. Currently, 'Traditional Chinese Medicine' (also known as TCM or 'Chinese style acupuncture') and 'Japanese style acupuncture' are commonly taught in Western acupuncture schools, and both styles include different techniques such as 'tonification' and 'dispersal'. So far, however, it has not been possible to objectively characterise these aspects of acupuncture needling.

The aim of this study was to use a newly developed force and motion sensor technology (acusensor) to quantify the linear and rotational movements of an acupuncture needle as well as the force and torque produced in real time during manual needle manipulation. We hypothesised that different styles (Chinese vs Japanese style acupuncture, hereafter referred to as 'style 1' and 'style 2', respectively) and types (tonification vs dispersal, hereafter referred to as 'technique 1' and 'technique 2', respectively) of needle manipulation would produce different needle motion and force patterns that could be quantified and differentiated from each other.

## METHODS

### Acusensor technology and measuring method

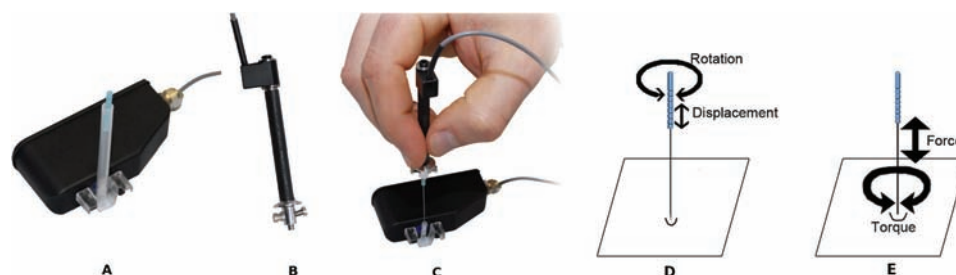
The measurement system consists of two individual sensors: a needle motion sensor and a needle force sensor (figure 1).

### Needle motion measurement

The motion sensor detects the two main components of needle motion that occur during manual manipulation, 'displacement' and 'rotation' (figure 1D). Displacement is the linear translation of the needle parallel to its longitudinal axis. This is sometimes referred to as lifting or thrusting. Rotation is the turning of the needle about its longitudinal axis. Displacement and rotation are measured by an optical sensor that can visualise the movement of microscopic asperities on the needle's surface. It produces measurements with a resolution of up to 2000 counts per inch of



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**Figure 1** Acusensor technology and illustration of measurement. A. Motion sensor shown with sterile, disposable needle and insertion tube. B. Force sensor. C. Force and motion sensors in use with needle. D,E. Illustration of needle motion (D) and forces (E) detected by motion and force sensors, respectively.

needle motion, at a frame rate of up to 7 kHz. This sensor, along with its associated electronics, is housed in a small module measuring approximately 30×20 mm and 10 mm thick (figure 1A). A sterile, single use, disposable needle guide with a 350- $\mu$ m diameter hole is provided through its thickness such that when an acupuncture needle is passed through it, the optical sensor is focused on the needle's shaft and detects rotation and displacement of the needle. An on-board microprocessor continually sums the incremental measurements of the optical sensor to produce absolute position estimates. In use, the practitioner identified the point to be needled, and the motion sensor was placed over this point. A sterile disposable acupuncture needle (0.20 mm diameter×40 mm length; Seirin, Weymouth, Massachusetts, USA) was passed through the needle guide and inserted into the skin. Needling was then carried out with the motion sensor held in place against the subject's skin by the practitioner's free hand. Prior to use, the motion sensors were calibrated using a two-axis actuator that generated known needle motions under computer control. The known needle motions were compared to the raw motion measurements to compute calibration coefficients in the form of scale factors and offsets.

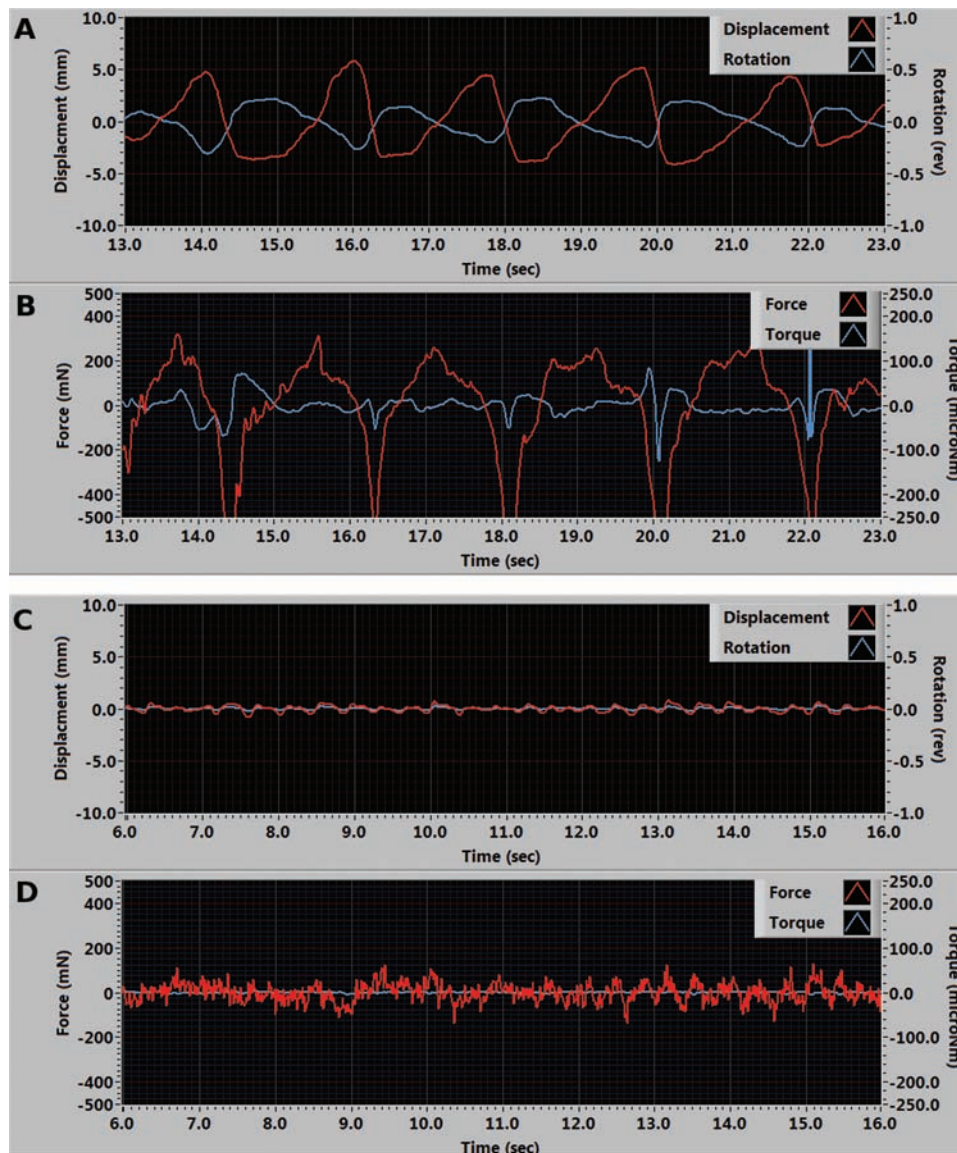
### Needle force and torque measurements

The measurement system's force sensor detects the mechanical loads developed by the tissue that tend to resist the needle's further motion. Needle 'force' is the linear force acting on the needle parallel to its longitudinal axis; needle 'torque' is the rotational force (torque) acting on the needle to resist its rotation (figure 1E). The force sensor consists of a lightweight aluminium sensing element housed within a tubular shell. The acupuncture needle is mechanically fixed to the distal end of this element, while the false handle that the practitioner grips is fixed to the proximal end. All loads that the practitioner applies to the false handle are therefore communicated through the sense element and into the acupuncture needle itself. Conventional strain gages bonded to the sense element detect the minute deformations that occur as a result of applied force and torque. In use, the force sensor is attached to the acupuncture needle prior to manipulation. When manipulation is then carried out, the force or

torque that the practitioner applies is directly measured by the force sensor. Prior to use, the force sensors were calibrated using hanging masses configured to generate known force and torque values applied to the sense element.

### Human in vivo testing

Testing was conducted at the New England School of Acupuncture (NESA), Newton, Massachusetts, USA. The testing protocol was approved by the New England Institutional Review Board. The acusensor was used to record and compare needling profiles produced by six experienced NESA acupuncture faculty. Three staff represented NESA's 'Chinese Acupuncture Studies' track (style 1), and three represented the school's 'Japanese Acupuncture Styles' programme (style 2). All practitioners were full-time teaching and clinical staff at NESA. Most of the faculty received either their full or additional training in either China or Japan (four out of six) and all studied under teachers from the country specific to their acupuncture style. Testing was performed in a concurrent session in which each faculty expert needled 6 acupuncture points bilaterally (12 points total) demonstrating contrasting types of manipulation ('tonification' as technique 1 and 'dispersal' as technique 2) randomised to the right/left side of the body in each of 12 healthy human subjects. All participants were informed and consented and signed consent forms. Faculty inclusion criteria were certification by the National Certification Commission for Acupuncture and Oriental Medicine and at least 5 years experience practicing the style of acupuncture they were representing. Faculty exclusion criteria were unfamiliarity with the style of techniques being demonstrated and lack of a valid local acupuncture license. Human subject inclusion criteria were men and women aged over 18 and good health defined as lack of acute or chronic illness not controlled by medication. Additional human subject exclusion criteria were pregnancy, acute illness, bleeding disorders, anticoagulant or corticosteroid medication. Faculty experience averaged (mean) 16.7 years with a range of 8–28 years. All but one had  $\geq 11$  years of practice experience. Human subjects were greater than 18 years old and included mostly acupuncture students.



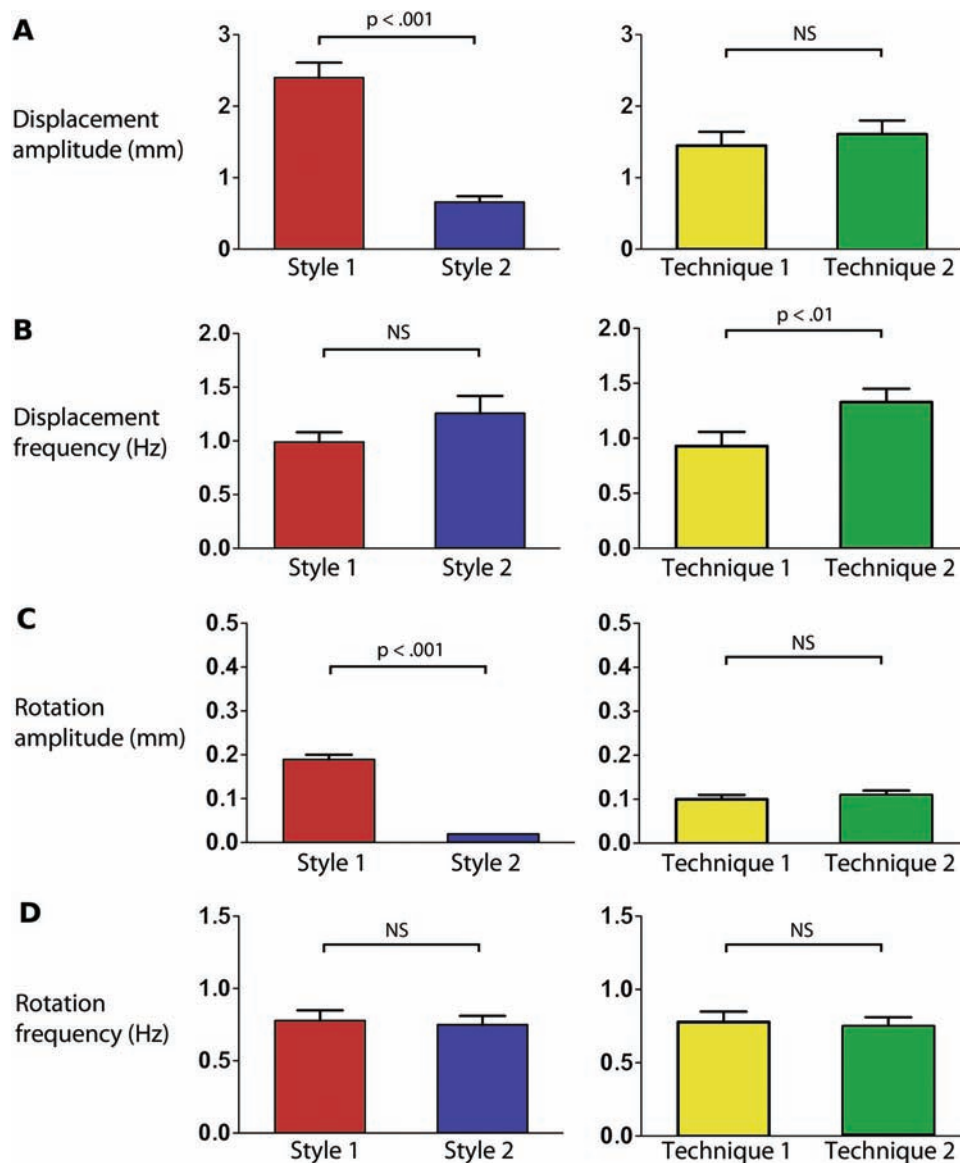
**Figure 2** Examples of real-time motion and force tracings created during needle manipulation. In (A) and (C), displacement is shown in red and rotation in blue. In (B) and (D), force is shown in red and torque in blue. A,B. Example of style 1 ('Chinese'), technique 2 ('dispersal'). C,D. Example of style 2 ('Japanese'), technique 1 ('tonification').

Six adjacent treatment tables were set up, each with its own needling sensor and research assistant. Faculty acupuncturists rotated from table to table. The following acupuncture points were located on each subject bilaterally and marked with a surgical marker before the testing began: Liv3, SP6, SP9, ST36, LI4 and LI11. Acupuncturist 1 began with subject A, acupuncturist 2 with subject B and so on. During the first rotation, each acupuncturist needled point no. 1 bilaterally, tonifying (technique 1) one side, dispersing (technique 2) on the other (sides randomised to needling type). Acupuncturists then rotated to the next table and repeated the same procedure at point no. 2 (techniques 1 and 2 again randomised to right and left sides). After the last rotation, each subject thus had received technique 1 and technique 2 needling at six pairs of points. During needling of each point, the needle was connected to the sensor, the motion and force data were

recorded, but the acupuncturist was not able to see the real time data. Acupuncturists were not shown any data until all the subjects had finished being tested.

### Data processing and analysis

The following outcome measures were calculated from the raw data: mean displacement amplitude, mean rotation amplitude, mean displacement frequency, mean rotation frequency, mean force amplitude and mean torque amplitude. Fast Fourier analyses of the raw data waveforms were performed to identify dominant frequencies. The peak amplitude of the dominant frequency was taken as the displacement and force amplitude outcome measures respectively. Analysis of variance was used to test for differences between techniques (technique 1 vs technique 2) and styles (style 1 vs style 2). The design corresponded to a replicated Latin square (two groups of six subjects being



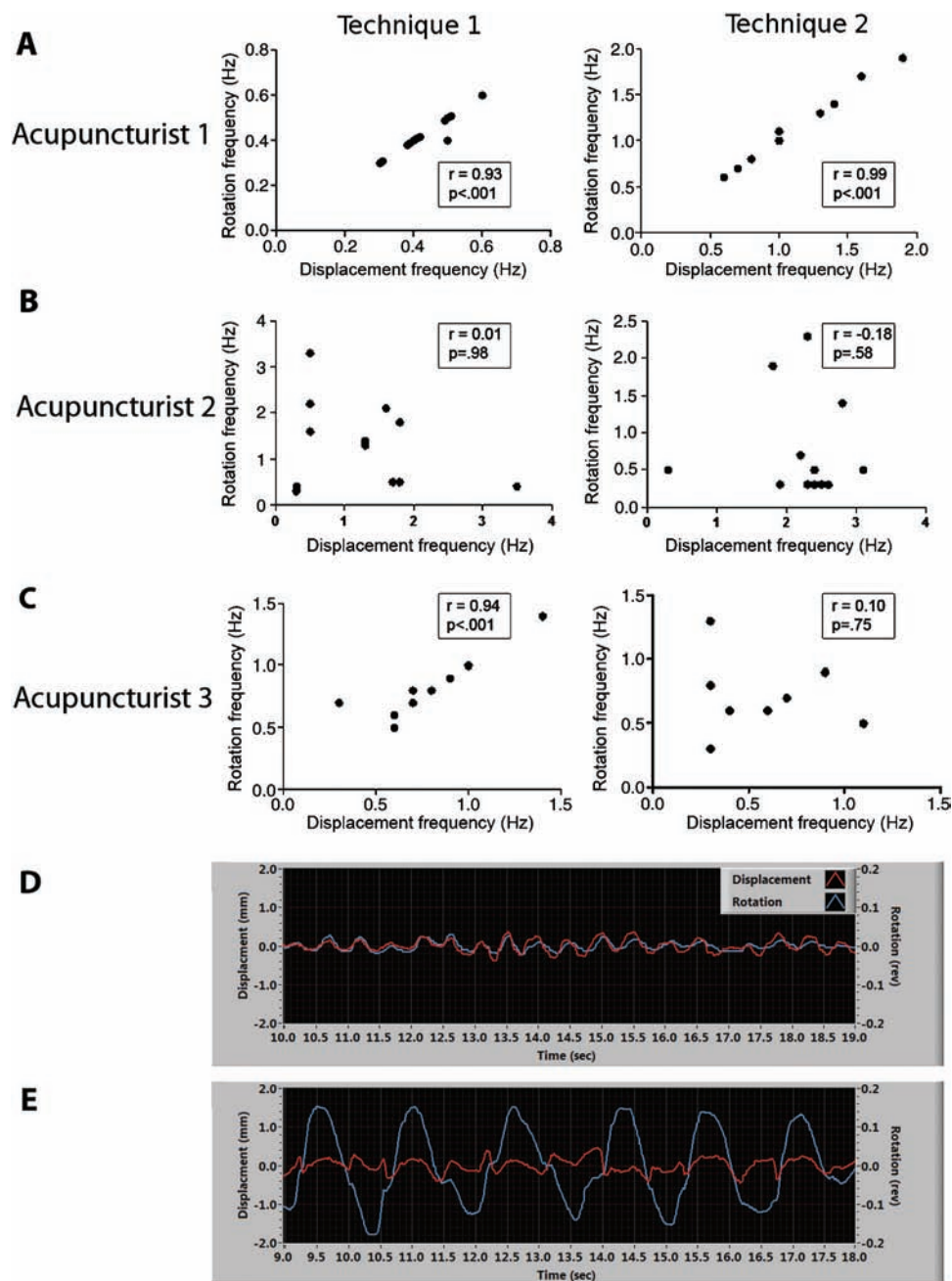
**Figure 3** Displacement and rotation measurements comparing needling styles (style 1 vs style 2) and techniques (technique 1 vs technique 2). A. Displacement amplitude. B. Displacement frequency. C. Rotation amplitude. D. Rotation frequency. Styles 1 and 2 correspond to 'Chinese' and 'Japanese' style acupuncture, respectively. Techniques 1 and 2 correspond to tonification and dispersal, respectively. All data presented as mean  $\pm$  SEM;  $n=12$  human subjects.

needed on six points by six acupuncturists) with type crossed with the above factors paired across sides within each test subject. The Latin square design was balanced for carryover effects of order. Style effects were tested using the variability between acupuncturists within each style ( $n=3$ ), which was stratified on point. Analyses were performed using PROC MIXED in SAS statistical software V.9 (SAS, Cary, North Carolina, USA).

## RESULTS

Examples of needling motion and force profiles are shown in figure 2. Faculty from the 'Chinese Acupuncture Studies' program (style 1) tended to use larger needle movements (figure 2A,B), while 'Japanese acupuncture styles' (style 2) staff performed smaller needle manipu-

lation (figure 2C,D). Needle motion measurements reflected these contrasting needle manipulation styles and techniques. When comparing style 1 versus style 2 needling, we found significant differences in mean displacement and rotation amplitude ( $p<0.001$  and  $p<0.001$ , respectively), but not displacement or rotation frequency ( $p=0.10$  and  $p=0.76$ , respectively) (figure 3). In contrast, when comparing technique 1 versus technique 2, we found significant differences in displacement frequency ( $p<0.01$ ), but not rotation frequency, displacement amplitude or rotation amplitude ( $p=0.27$ ,  $p=0.21$  and  $p=0.42$ , respectively) (figure 3). Neither displacement nor rotation amplitude differences between style 1 and style 2 were dependent on manipulation technique ( $p=0.60$  and  $p=0.74$  for style $\times$ technique interactions). Similarly, displacement frequency differences between technique

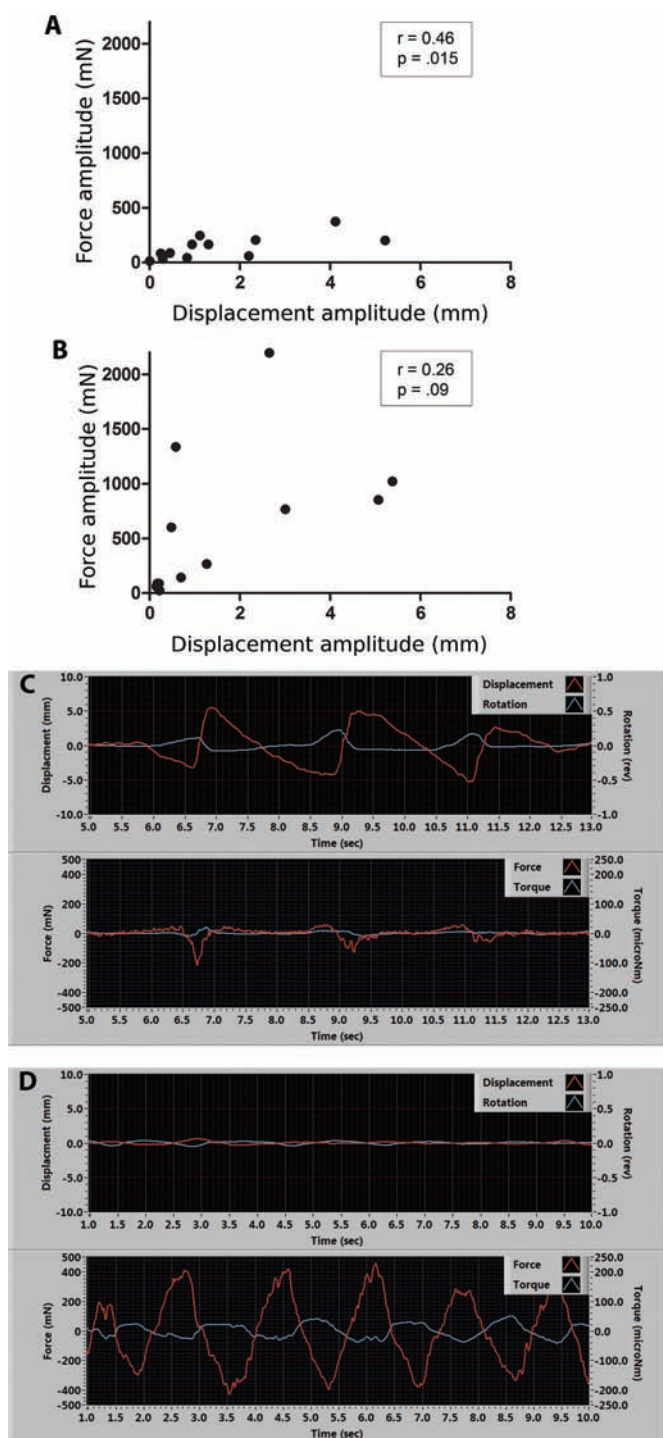


**Figure 4** Relationship between needle displacement and rotation. A–C. Examples of three acupuncturists showing different degrees of correlation between displacement frequency and rotation frequency. Within each graph, individual points correspond to individual subjects. The degree of correlation between displacement and rotation was high in both techniques for the acupuncturist shown in (A), and low in both techniques for the acupuncturist shown in (B). The acupuncturist shown in (C) had a high correlation for technique 1 but low correlation for technique 2. D,E. Needle displacement and rotation tracings illustrating synchronised versus non-synchronised needle motion. Displacement and rotation are occurring at the same frequency in (D) but at different frequencies in (E).

1 and technique 2 were not dependent on style ( $p=0.48$  for type $\times$ style interaction). Thus, needle motion measurements were able to quantify specific components of needling (displacement and rotation amplitude) that differentiated style 1 from style 2 as well as a component (displacement frequency) of needling that differentiated technique 1 from technique 2.

We also observed that the correlation between displacement and rotation frequency was acupuncturist

dependent: in some acupuncturists, linear and rotational movements were performed at a similar frequency (figure 4A), whereas in others the frequencies were more independent of each other (figure 4B). Furthermore, in some acupuncturists, this relationship was technique dependent (figure 4C shows high correlation between linear and rotation frequency for technique 1 but not technique 2). Figure 4 D,E show examples of synchronised (figure 4D) and non-synchronised (figure 4E) needle motion.



**Figure 5** Relationship between needle displacement and needle force. A,B. Relationship between force and displacement, illustrating subject-dependent needling variability. (A) and (B) represent different subjects; within each graph, each plotted value represents a different needling location on the body. A. Needle force was low regardless of how much needle displacement occurred. B. Greater and more variable amount of needle force is observed, indicating a more variable amount of ‘tissue grasp’. C,D. Real-time experimental tracings illustrating the variable relationship between needle force and needle displacement in two different subjects; (C) high amplitude needle motion associated with low force and torque; (D) low amplitude needle motion associated with high force and torque.

In contrast to the group differences found with needle motion measurements, we found no significant differences in needle force and torque between needling styles and techniques. There was also no significant overall correlation between needle motion and needle force. It is interesting to note that at least some of the variability in needle force was subject dependent: as shown in figure 5A, some subjects exhibited low tissue forces regardless of how much needle motion occurred, while in others (figure 5B) tissue force was more variable. Figure 5C further illustrates that, in some cases, large amplitude needle motion produced very small forces, while in other cases, much larger forces resulted from a very small amount of needle rotation (figure 5D).

## DISCUSSION

While descriptions of a wide range of needling styles and techniques abound in acupuncture literature,<sup>1-6</sup> methods have been lacking to objectively quantify parameters associated with acupuncture needling. The various motion and force tracings shown in figures 2, 4 and 5 illustrate the complex and variable nature of acupuncture needle manipulation, even within the limited context of this study. Despite this variability, however, some statistically significant patterns emerged, such as a greater displacement amplitude for ‘Chinese’ (style 1) compared with ‘Japanese’ (style 2) acupuncture which was independent of technique, as well as a greater displacement frequency for dispersal (technique 2) compared with tonification (technique 1) which was independent of style. Importantly, the small number of acupuncturists who participated in the study limits our ability to draw conclusions regarding the generalisability of these findings. Our results nevertheless suggest that needle motion measurements could be useful to document and classify the broad and heterogeneous range of acupuncture styles and techniques that are currently practiced throughout the world.

It is becoming increasingly clear that the heterogeneity of acupuncture needling methods constitutes a major challenge in acupuncture research.<sup>7-9</sup> Having the ability to quantify needle motion will enable the systematic exploration of the relationship between acupuncture needling methods and clinical outcomes. Animal research has shown that differences in the amplitude of needle rotation can affect cellular responses in subcutaneous connective tissues.<sup>10 11</sup> It is plausible that different manual needling techniques impact local tissues and nerves distinctly, and play a role in clinical outcomes. However, until now, this has been beyond the scope of investigation.

In contrast to needle motion, needle forces did not differ significantly when compared across styles or techniques. This lack of systematic difference between groups may be related to the observation that the amount of needle motion needed to elicit a given amount of force varied widely across subjects. This suggests that tissue variability in patients may be a more important factor in determining needle force differences than either style or technique.

## Summary points

This article describes a new method for quantifying acupuncture needle movement.

In summary, the results of this study show that measurement of needle motion and force during acupuncture is feasible. Future investigations could be designed to describe the incidence and usage patterns of various needling techniques, investigate whether optimal acupuncture treatment parameters can be identified, and illuminate potential mechanisms of action.

**Contributors** RD codesigned the study, monitored data collection, analysed the data, and drafted and revised the paper. He is the guarantor. DC oversaw engineering of the device used, provided device support, analysed data and drafted sections of the paper. GB designed the statistical plan, analysed the data and drafted relevant sections of the paper. JD oversaw the testing at NESA and contributed to writing and editing. HL codesigned the study, monitored data collection, analysed the data and revised the paper.

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