Quantification of Motion Palpation

Hervé Kasparian, DO (France)
Ghislaine Signoret, DO (France)
Jérôme Kasparian, PhD

From Cabinet d'Ostéopathie Saint-Pierre in Tonneins, France (Mr H. Kasparian and Mrs Signoret); and University of Geneva in Switzerland (J. Kasparian).

Context: The palpation of motions is at the heart of the practice of foreign-trained osteopaths. When practicing osteopathic manual therapy (care provided by foreign-trained osteopaths) in the cranial field or osteopathic cranial manipulative medicine, the palpation of small motions (several tens of micrometers) is a key process. However, to the authors' knowledge, the smallest detectable motion has not been identified.

Objective: To quantify motion detection capacity by passive palpation.

Methods: Participants were instructed to hold a mechanical device containing a micrometric actuator between their hands and report when they felt motion while 6 series of 27 random motions were generated by the actuator. After each series, if a participant succeeded or failed to detect motion with a confidence level of greater than 98%, the motions in the next series were set to a smaller or larger magnitude, respectively. After 6 series, the individual motion detection capacity was recorded. Statistical significance was set at P=.02.

Results: A total of 21 participants were selected, comprising 14 osteopaths and 7 nonosteopaths. The average performance of the sample was 148 μm. Thirteen participants (62%) perceived motions of 200 μm or less, and 7 participants (33%) detected motions of 50 μm or less with bare hands. Osteopathic training did not notably affect the performance. Osteopaths were twice as likely to claim detection of nonexisting motions than to miss existing ones, whereas nonosteopaths were equally subject to both types of errors.

Conclusion: The data show human passive palpatory sensitivity to be in the range of several tens of micrometers. This range is comparable to that reported for calvarial motion (10-50 μm).

One of the uses of palpation is to sense motion. In osteopathic manual therapy (care provided by foreign-trained osteopaths) and osteopathic manipulative medicine, examiners are required to palpate motions of very small amplitudes. It has been claimed that experienced therapists can perceive motions of 90 μm[1] and untrained persons, 1 mm, but our review of the literature did not reveal scientific proof of these figures.

Osteopathic cranial manipulative medicine involves detecting micrometric cranial motions.[2-12] Some believe that these motions are "too small to be felt."[13] Detecting a motion occurring outside an examiner's body depends on several somatosensory inputs as well as multiple central nervous system integrations.[14-18] Kinesthetic sense (mainly through muscle

and skin stretch, since the motion is transmitted to the joint) and epicritic sensation (compression of superficial tissues) could help.

Several aspects of kinesthetic senses[19] have been quantified[20]: the minimum perceivable difference in the magnitude of a frontal force is 22%.[21] When a metacarpophalangeal joint is being passively flexed, the sensitivity of muscle spindle afferent fibers is 0.3 impulsions per second per degree of flexion of the metacarpophalangeal joint.[15] One can therefore expect sensitivity in the order of 0.1° or less at the nerve level, depending on the number of fibers.

Several studies have measured epicritic sensation using cutaneous 2-point discrimination,[21,22] which characterizes the ability of the fingertip to discriminate between 2 points located 1 to 3 mm away from each other.

However, because the detection of motion is a complex process including multiple parameters[24-27] and involving multiple physiologic modalities, the knowledge we currently have about each of these modalities is not sufficient to answer our research question: What is the smallest magnitude of motion that can be sensed by means of palpation? In the present study, we tested the ability of foreign-trained osteopaths and nonosteopaths to detect controlled motions of 10 to 1000 μm amplitude using a mechanical setup. We hypothesized that motions in the range of tens of micrometers can effectively be detected by passive palpation, with or without osteopathic training.

Methods

The study took place during the first quarter of 2014 in the clinic of the Institut Privé d'Enseignement Ostéopathique in Pantin, France. Volunteers were recruited from the clinic and from the local neighborhood. Institutional review board approval was not required. Participant consent was obtained after the concept of the study and how the apparatus worked was explained. Participants needed to meet the following inclusion criteria: aged between 20 and 35 years; foreign-trained osteopaths had to have a DO degree or to be a student in his or her last (fifth) year in an osteopathy program; and nonosteopaths had to be in a profession that did not involve fine palpatory perception. Participants with a sensorimotor disease or history of injury to an upper limb were excluded.

Motion detection was determined using a mechanical device (*Figure 1*). A cylindrical plastic box 12.7 cm in diameter was vertically cut on both sides to allow dilatation. The 2 halves were connected at the bottom by an articulation and at the top by a rubber band. Inside the box at midheight, an actuator (Thorlabs Z806) was placed to control the box diameter. The specified resolution of the actuator motion was 29 nm—almost 1000 times smaller than the smallest motions we investigated. The actuator was used to produce repeatable translations of 10 to 1000 μm in magnitude. These translations were converted into diameter expansion or retraction with the same magnitude. The device was used to produce several series of 27 events. Each event could be a single motion of expansion, retraction, or no motion. The acceleration was set to 1 mm/s^2 and the maximal velocity to 1 mm/s. The type of event was chosen randomly using the RAND function in Excel (Microsoft Corporation), with 25% probability for expansion, 25% for retraction, and 50% for no motion. Each event lasted approximatively 1 second and was followed by 5 seconds of idle time.

Before the procedure began, participants were shown how to use the device and invited to practice until they felt familiar with the procedure. The instructions were repeated, and training was offered to participants each time the amplitude of motion was changed so that they knew what type of motion they would be feeling for. During the experiment, participants listened to a soundtrack via headphones synchronized with the operation of the actuator. The soundtrack played a sound signaling the beginning and end of each event, and it played white noise during the event to mask any noise made by the actuator. During the idle time, participants had several seconds to report their sensation by answering *yes* (I
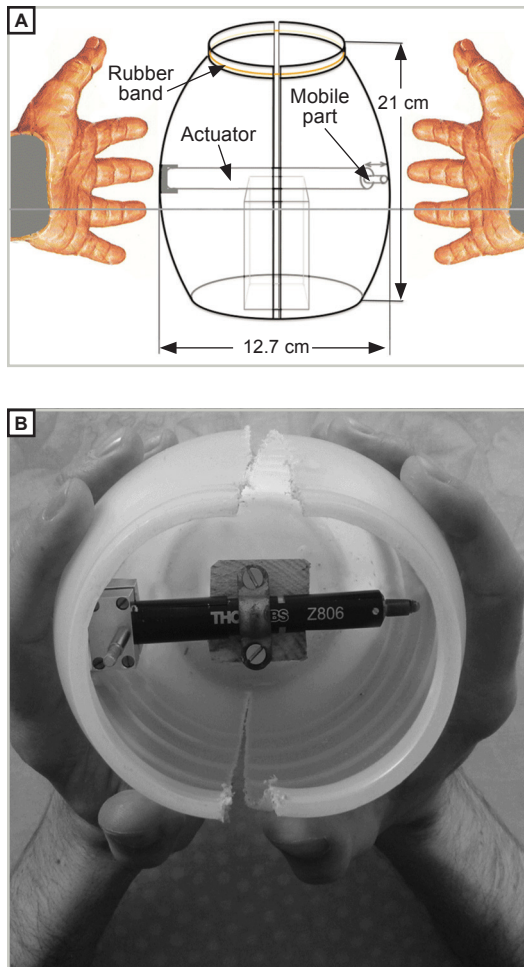
Figure 1.
Experimental setup for motion detection using a mechanical device with an actuator. A, schematic (side view); B, photo (top view).

felt motion) or *no* (I felt no motion). An answer was requested for all events.

Participants were considered able to detect motions of a given magnitude if they correctly reported 19 or more motions or no motions out of the 27 events. According to the χ^2 test, this 70% performance ensures the statistical significance of the result ($P<.02$; ie, it deviates from random answers with 98% confidence). This strict and asymmetric criterion prevents any overestimation of a participant's performance. Each time a participant demonstrated this level of performance for a given magnitude of motion, the magnitude was decreased for the next series of events. Conversely, if he or she gave 18 or fewer good answers, the magnitude was increased for the next series. This dichotomous approach was repeated over 6 series. We first tested the participants' ability to detect a 1000-µm (M_1) amplitude motion and assumed, based on preliminary dimensioning tests, that he or she would fail to detect a 10-µm (m_1) amplitude motion. At each new series (numbered n), we knew that the smallest magnitude of motions a participant could detect was included in the interval $[m_n;M_n]$, where m_n is the largest one for which he or she failed to detect, and M_n is the smallest one for which he or she successfully detected. To reduce the interval between m_n and M_n, we tested a magnitude of motion (μ_n) intermediate between m_n and M_n during the next series. μ_n was the geometrical mean of m_n and M_n: $\mu_n = \sqrt{m_n \times M_n}$.

By using a geometrical mean rather than an arithmetic mean, we limited the number of series and the experimental time required to reach a given precision, therefore reducing biases related to the participants' limited attention time or fatigue. The whole procedure required approximately 30 minutes per participant. After 6 series, the interval was reduced so $M_6/m_6 = 1.15$ (15% precision). The motion detection capacity of a participant was then considered to be M_6, ie, the smallest motion he or she reliably detected.

To avoid over- or underestimations of the device's movements, we requested that the participants place their hands on both sides of the box, at a position marked at the level of the actuator.

The double-blind operation was ensured as follows: We checked that the box adequately dampened torque, torsion deformations, and vibrations of the actuator. Furthermore, during the experiment, participants wore eye and ear coverings, and their communication was restricted to an interviewer who had no knowledge of the actuator's motion.

Statistical Analysis

As previously detailed, the number of events in each series was chosen so that according to a χ^2 test, statistical significance of $P<.02$ was reached for a performance of 70% (19/27 correct answers). The difference between groups was assessed by a t test when comparing mean values and a χ^2 test when comparing the rate of false-positive and false-negative detections.

Results

A total of 21 participants met the inclusion criteria, with 14 osteopaths and 7 nonosteopaths. The mean age was 26.6 years, and 16 (76%) were women. The mean hand size from the second to the fifth metacarpal joint was 7.8 cm and 7.6 cm for osteopaths and nonosteopaths, respectively. As shown in *Figure 2*, the minimum motion detected by the participants ranged from 15 to 365 μm, with the exception of 1 participant, whose minimum detected motion was 866 μm. Furthermore, 13 of 21 participants (62%) could perceive a motion of 200 μm or less, and 7 of 21 (33%) could detect a motion of 50 μm or less.

We compared the results of the 2 groups. As detailed in *Table 1* and *Table 2*, the mean (SD) minimum motion detected by the 7 nonosteopaths was 123 (89) μm and by the 14 osteopaths was 161 (131) μm. The results of the osteopaths ranged from 15 to 365 μm, with 1 participant at 866 μm. One-third of the osteopaths tested detected motions between 15 μm and 43 μm. The t test indicated that the between-group differences in mean minimum motion detected could not be considered significant ($P>.2$), showing that osteopaths and nonosteopaths had similar motion detection abilities. However, between-group differences in the distribution of failed detections were statistically significant. Nonosteopaths equally provided false-positive (162) and false-negative (172) answers. Conversely, osteopaths provided twice as many false-positive (444) than false-negative (233) answers (*Figure 3*). In other words, osteopaths were more likely than nonosteopaths to report a nonexisting motion than
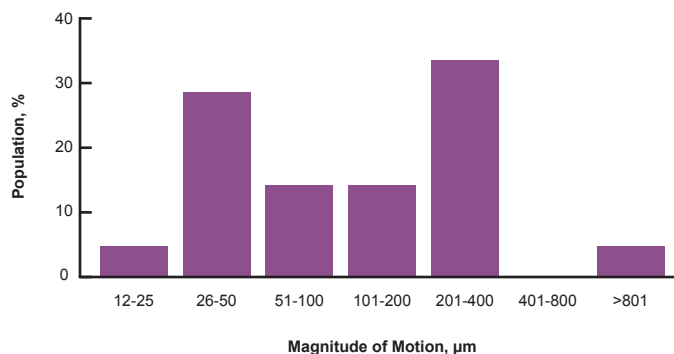

Figure 2.
Distribution of the smallest detectable motion among foreign-trained osteopaths and nonosteopaths.

to fail to report an existing motion. This difference between the 2 groups in the rate of false-positives and false-negatives is highly significant ($\chi^2=27$; $P<.001$). Between-group differences in the distribution of correct responses was also significant: negative answers (ie, no motion detected) represented 462 of 827 (56%) correct responses for nonosteopaths vs 802 of 1667 (48%) for osteopaths ($\chi^2=13$; $P<.001$).

To explore these unexpected differences, we performed a complementary test on the same sample with a similar procedure. This time participants were asked to identify the direction of the motion (ie, expansion or retraction) in 6 series of 27 motions (a movement occurred for each event), in which direction was chosen randomly, with 50% probability of expansion and 50% probability of retraction.

In contrast with the distribution of failed detections in the motion detection test, the 2 groups exhibited differences that were not statistically significant ($\chi^2=0.16$; $P=.69$): the ratio of false expansions to false retractions was 56%:44% for osteopaths and 57%:43% for nonosteopaths. Furthermore, we found a substantial difference between detecting a motion and characterizing its direction. For an individual to reliably characterize a motion's direction, the motion needed to have approximately 4 times the minimum detectable amplitude identified for that individual.

Table 1.
Distribution of Motion Detection Capacities Among Foreign-Trained Osteopaths and Nonosteopaths (N=21)[a]

	Nonosteopaths	Osteopaths	Whole Sample
Best	28	15	15
Worst	237	866	866
Mean (SD)	123 (89)	161 (131)	148 (127)
Median	100	166	117

[a] Data are given as micrometers.

Table 2.
Degree of Perception of Motion by Foreign-Trained Osteopaths and Nonosteopaths (N=21)[a]

Motion	Nonosteopaths	Osteopaths	Total
≤50 μm	2 (29%)	5 (36%)	7 (33%)
≤100 μm	4 (57%)	6 (43%)	10 (48%)
≤200 μm	5 (71%)	8 (57%)	13 (62%)
≤300 μm	7 (100%)	11 (79%)	18 (86%)

[a] Data are given as No. (%) of participants perceiving motion.

Discussion

One-third of our sample could detect a motion of 50 μm or less with their bare hands, clearly demonstrating that passive palpation enables the detection of motions in the range of tens of micrometers, although not all individuals are capable of this performance. This range is in line with the measured cranial motion reported in the literature.[2-12] In particular, Laval et al[9] used an eddy current sensor to measure the motion of the frontal bone in 100 young adults and found a periodic motion with an amplitude of 10 to 50 μm and a frequency of 0.16 Hz, independent from respiratory motion.

Note, however, that the current study did not reproduce the slow, continuous, and periodic motion of a living crane. For motions smaller than 50 μm, no par-

ticipant was able to reliably identify the direction of the motion. This finding is consistent with the results of Nelson et al,[11] who demonstrated the ability to feel the rhythm of cranial motion but not its direction. Besides, the measured sensitivity of motion can be expected to depend on the associated speed and acceleration. Further studies will be necessary to characterize the influence of these parameters on motion detection.

Surprisingly, the only statistically significant difference between the osteopaths and nonosteopaths in our study was in the rate of false-positive detections. The latter represents two-thirds of all errors made by the osteopaths. This difference could be the manifestation of a mental posture from osteopaths who "want to feel something" because they have been trained to do so. As Kalaska[16] said:

> ... the generation of a central neural representation of the mechanical stimulus is only part of the tactile perceptual process. It is also influenced by the behavioral, attentive, and motivational state.

The nonosteopath group in the current study had nothing to prove, and they had as many false-positive answers as they had false-negatives. They also had more true-negative answers than did osteopaths. It might be that in cases of doubt, nonosteopaths tended to report no feeling of movement. This interpretation—the presence of a mental bias—might be confirmed by the fact that both groups had a similar error distribution for the detection of the motion direction. In the direction-detection test, no participant was pressured to report or not report movement, thus introducing no bias in the type of their errors (false expansion/false retraction).

Note that the 71% of correct answers observed in both groups is not a representative characteristic of the population but is the mechanical consequence of our protocol: the limit between failure and success in a given series was set at 70%.

The present study provides no information on the neural pathways used for this type of palpation. We can

assume that they could depend on the palpating strategies used by the osteopaths; looking for deep relaxation could help a motion to be fully transmitted to the wrist. Trigonometric calculation shows that 100-µm motion is converted in 0.1° extension of the wrist. Future studies should explore this issue.

Conclusion

One-third of our sample was able to detect a movement smaller than 50 µm. Because this ability is not universal, osteopaths and osteopathic physicians can correlate this information with shape, density, and tension: each element provides valuable information for palapatory examinations. The methods used in the present study may be useful for osteopathic training in the perception of small motions. This objectification and quantification of human palpation capacity provides a foundation for osteopathic science and research in this area and should encourage further investigation on the mechanism of action of osteopathic manual therapy and on osteopathic cranial manipulative medicine.

Author Contributions

All authors provided substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; all authors drafted the article or revised it critically for important intellectual content; all authors gave final approval of the version of the article to be published; and Mr H. Kasparian and Mrs Signoret agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Figure 3.
Distribution of answers (total; 2492) showing the contrast in false-positives between osteopaths and nonosteopaths.

References

1. Ehrenfeuchter WC, Kappler RE. Palpatory examination. In: Chila A, ed. *Foundations of Osteopathic Medicine*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins; 2011.

2. Frymann VM. A study of the rhythmic motions of the living cranium. *J Am Osteopath Assoc*. 1971;70(9):928-945.

3. Retzlaff EW, Michael DK, Roppel RM. Cranial bone mobility. *J Am Osteopath Assoc*. 1975;74(9):869-873.

4. Heifitz MD, Weiss M. Detection of skull expansion with increased intracranial pressure. *J Neurosurg*. 1981;55(5):811-812.
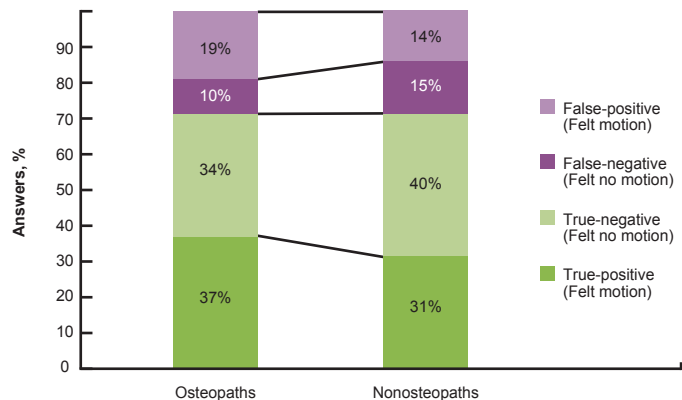
5. Oudhof HA, Van Dooremaalen WJ. Skull morphogenesis and growth: hemodynamic influence. *Acta Anat (Basel)*. 1983;117(3):181-186.

6. Pitlyk PJ, Piantanida TP, Ploeger DW. Noninvasive intracranial pressure monitoring. *Neurosurgery*. 1985;17(4):581-584.

7. Adams T, Heisey RS, Smith MC, Briner BJ. Parietal bone mobility in the anesthetized cat. *J Am Osteopath Assoc*. 1992;92(5):599.

8. Ballard RE, Wilson M, Hargens AR, et al. *Noninvasive Measurement of Intracranial Volume and Pressure Using Ultrasound*. Book of Abstracts, Life Sciences and Space Medicine Conference, March 5-7, 1996, Houston, TX.

9. Laval Y, Villermain-Lecolier G, Billaudel P. Mesure des rythmes tissulaires de la microcirculation cranio-sacrée: de l'approche manuelle ostéopathique à l'expérimentation scientifique. *Biométrie Humaine et Antropologie*. 1999;17:82.

10. Moskalenko YE, Kravchenko TI, Gaidar BV, et al. Periodic mobility of cranial bones in humans [article in Russian]. *Fiziol Cheloveka*. 1999;25(1):51-58.

11. Nelson KE, Sergueff N, Lipinski CM, Chapman AR, Glonek T. The cranial rhythmic impulse related to the Traube Hering Meyer oscillation: comparing laser Doppler flowmetry and palpation. *J Am Osteopath Assoc*. 2001;101(3):163-173.

12. Downey PA, Barbano T, Kapur-Wadhwa R, Sciote JJ, Siegel MI, Mooney MP. Craniosacral therapy: the effects of cranial manipulation on intracranial pressure and cranial bone movement. *J Orthop Sports Phys Ther*. 2006;36(11):845-853.

13. Rogers JS, Witt PL. The controversy of cranial bone motion. *J Orthop Sports Phys Ther*. 1997;26(2):95-103.

14. Bigley GK. Sensation. In: Walker HK, Hall WD, Hurst JW, eds. *Clinical Methods: The History, Physical, and Laboratory Examinations*. 3rd ed. Boston, MA: Butterworths; 1990.

15. Edin BB, Vallbo AB. Dynamic response of human muscle spindle afferent to stretch. *J Neurophysiol.* 1990;63(6):1297-1306.

16. Kalaska JF. Central neural mechanisms of touch and proprioception. *Can J Physiol Pharmacol.* 1994;72(5):542-545.

17. Braillon G. *Le Système Nerveux Central.* Paris, France: Doin éditeur; 1996.

18. Marieb EN. *Anatomie et Physiologie Humaine.* 6th ed. Paris, France: Pearson; 2005.

19. Proske U, Gandevia SC. The kinaesthetic senses. *J Physiol.* 2009;587(pt 17):4139-4146. doi:10.1113/jphysiol.2009.175372.

20. Edin BB. Quantitative analyses of dynamic strain sensitivity in human skin mechanoreceptors. *J Neurophysiol.* 2004;92(6):2322-2343.

21. van Beek FE, Tiest WM, Kappers AM. Anisotropy in the haptic perception of force direction and magnitude. *IEEE Trans Haptics.* 2013;6(4):399-407. doi:10.1109/TOH.2013.37.

22. Chandhok PS, Bagust J. Differences between the cutaneous two-point discrimination thresholds of chiropractic students at different stages in a 5-year course. *J Manipulative Physiol Ther.* 2002;25(8):521-525.

23. Foster IE, Bagust J. Cutaneous two-point discrimination thresholds and palpatory sensibility in chiropractic students and field chiropractors. *J Manipulative Physiol Ther.* 2004;27(7):466-471.

24. Wilmot E [dissertation]. British College of Naturopathy and Osteopathy; 1989 http://edwardwilmotosteopathy.com /EPM/introduction.htm. Accessed August 21, 2015.

25. Howell JN, Conatser RR, Williams RL II, Burns JM, Eland DC. Palpatory diagnosis training on the virtual haptic back: performance improvement and user evaluations. *J Am Osteopath Assoc.* 2008;108(1):29-36.

26. Nyberg RE, Russell Smith A Jr. The science of spinal motion palpation: a review and update with implications for assessment and intervention. *J Man Manip Ther.* 2013;21(3):160-167. doi:10.1179/2042618613Y.0000000029.

27. Kim SY, Ryu JH, Lee W. Palpation simulator with stable haptic feedback. *Minim Invasive Ther Allied Technol.* 2015;24(4):211-217. doi:10.3109/13645706.2014.987677.

Download *JAOA* PowerPoint Slides

Readers of can download Microsoft PowerPoint slides of figures published in *The Journal of the American Osteopathic Association*. When viewing the figure in the full text article on JAOA.org, simply click on the link "Download as PowerPoint slide." Readers can also download all figures in an article by selecting the option "PPT Slides of All Figures" in the middle column of the Web page.