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Reliability of Smartphone inclinometry to measure upper cervical range of motion.

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Abstract:

Context: Assessment of upper cervical range of motion (UCROM) and mobility is commonly performed in the clinical setting for patients suffering from headache, neck pain and vestibular dysfunction. Reliable and reproducible measurement of this motion is often difficult or too expensive to perform in the clinical setting. Smartphone applications, utilizing the device's internal gyroscope, offer an easy and inexpensive means of measuring UCROM, but their reliability has not been reported in the literature. **Objective:** Assess the reliability of an inclinometer application, installed on two different devices (iPhone6 (IP), Andriod (AN)), to measure UCROM in a healthy population. **Design:** Two examiners assessed passive UCROM. Each examiner was assigned to a specific smartphone and a repeated measures design consisting of three trials for each examiner-phone was performed. The order of testing was randomized and the examiners were blinded to UCROM measures. **Setting:** Laboratory **Participants:** 38 subjects (19F, 19M; 23.8±1.2 yrs) without pain or injury to the neck and spine for at least 3 months. **Intervention:** Each examiner passively flexed the head fully and then rotated the head fully in one direction then in another. Peak rotation measures were recorded from each smartphone. Three trials were performed for each phone with a 2-minute break between examiners/phones. **Main Outcome Measures:** Intraclass Correlation Coefficient (ICC) using a two way mixed, absolute agreement model were obtained (1) between each examiner-phone and (2) within each examiner-phone for the measurements in each rotation direction. **Results:** Inter-phone/examiner reliability comparing average peak and total UCROM for each device were excellent (0.87, 0.81). Intra-phone/examiner reliability, determined across three trials, was also excellent (AN Right Rot. = 0.91, AN Left Rot. 0.96, IP Right Rot. = 0.98, IP Left = 0.95 Rot.). **Conclusions:** UCROM can be reliably measured using a smartphone inclinometer application.

Measurement of cardinal plane cervical range of motion is routinely performed in physical therapy.[1] Cardinal plane motion such as cervical flexion and extension are important clinically, but have not been found to identify specific limitations in upper cervical mobility, which could be causing or contributing to the patient's pain and dysfunction.[1,2] Accurate assessment of upper cervical mobility and upper cervical range of motion (UCROM) are, critical in the evaluation and treatment of those with pathology that can be influenced by the upper cervical spine such as headache, migraine, vertigo, concussion and post-concussion syndrome.[1-6]

The cervical flexion and rotation test was developed specifically to assess mobility in the upper cervical spine. It is a commonly used manual examination procedure, and is considered a reliable measure of upper cervical range of motion (UCROM).[2,6-8] Blanpied et al[2] state that due to its high level of specificity, 0.91, the cervical flexion and rotation test should be performed to rule in cervicogenic headache.

Research investigating vertigo, concussion, post-concussion syndrome, migraines and cervicogenic headache all state that the upper cervical spine, atlanto-axial and atlanto-occipital joints, must be evaluated and mobility deficits addressed, in patients suffering from these conditions.[1-6] Despite these recommendations, there are a limited number of publications describing the prevalence of UCROM mobility deficits in these varying patient populations.[6,9] This lack of foundational information may be attributed to the high cost and difficulty in accurately measuring UCROM using the currently available gold standard techniques such as video motion analysis, radiographs and the cervical range of motion (CROM) device (Performance Attainment Associates; Lindstrom, MN). Identifying an inexpensive and readily available tool to measure UCROM would allow researchers and clinicians to effectively measure UCROM and better define upper cervical mobility deficits as it relates to these varied conditions.

Improvements and increased availability of portable and inexpensive technologies currently allow smartphone users to assess three dimensional movements in real time using various applications. This technology has been found to be both reliable and valid when measuring range of motion in multiple joints including cardinal plane range of motion of the cervical spine.[9,10]

There is however, a gap in the literature demonstrating the efficacy of this technology when specifically measuring UCROM. One inclinometer based application, Clinometer (Plaincode, Stephanskirchen Germany), utilizes the device’s internal sensors to measure multiplaner movements in real time with a self-reported measurement accuracy of ±0.1°. This reported accuracy is comparable to the more expensive gold standard measures utilized to measure UCROM in a laboratory setting. To our knowledge, there are no published works collaborating their claims or supporting the use of this particular application to measure UCROM in humans. The purpose of this study to evaluate the reliability of the Clinometer application in both an iPhone (IP) or Android (AN) device when measuring UCROM in a laboratory setting.

METHODS

Two doctorally trained, clinical researchers with more than 40 years of combined manual clinical experience performed this laboratory study. Each examiner was assigned to measure UCROM using either the IP or AN device and were blinded to their own UCROM measures.

A convenience sample of 38 healthy, college age students (19F, 19M; 23.8±1.2 years of age) (Table 1) without limited range of motion, stiffness, pain or injury in the neck and spine for at least 3 months took part in this study. All participants read and signed the appropriate informed consent documentation as required by Institutional Review Board, who approved this study.

Order of testing, AN vs IP, was randomized using a coin, with heads indicating AN and tails indicating IP. The direction that the head was rotated first was also randomized using a coin with heads indicating right and tails indicating left.

Subjects were placed in a seated position, as described by Amiri et al.[8] with their hair suitably positioned to allow visualization of the device and to ensure that the device properly secured to the head. (Universal Head Strap, Velocity Clip, Lake Tahoe, CA) fixation (Figure 1).

1. The smartphone and head strap were positioned on the subject’s head and straps tightened to prevent movement.
2. The subject’s head was then passively flexed to end range with neutral rotation and neutral side bending by the examiner. The head strap position was adjusted until such time as the application read zero, thereby establishing a “neutral” starting position. The subject’s head was actively returned to the upright starting position.
3. The subject then maximally flexed, extended, rotated right, rotated left, side bent right and side bent left actively, in order to normalize cervical planes of cardinal motion and ensure that the head strap and phone combination remained securely fixated on the head. The subject’s head was actively returned to the upright starting position.
4. The examiner passively flexed the subject’s neck to end range.
5. The examiner passively rotated the head in one direction until no further range of motion was perceived by the examiner or the subject reported pain. UCROM was recorded by a research assistant to ensure that the examiner moving the head was unaware of their measures.
6. The head was passively rotated in the other direction and the measure recorded, as above.

7. The subject then returned their head to its normal resting position and the subject rested for 20 seconds.
8. Steps 1 through 7 were repeated in order to obtain 3 trials for that device.
9. The head strap and phone was then removed and steps 1 through 8 were repeated to obtain three trials for the other device.

If at any time the subject or examiner reported or perceived a lack of fixation of the device the trial was discarded and the entire testing procedure was repeated. This protocol produced three measures of UCROM in each direction (left, right) for each device. Data was analyzed using SPSS (IBM Corporation, version 24). Intraclass Correlation Coefficient (ICC) were calculated using a two-way mixed, absolute agreement model for (1) between each examiner-phone and (2) within each examiner-phone for the measurements in each rotation direction.

RESULTS

Total UCROM measures were calculated for each device by adding the average left and average right UCROM measurements. Average left, right and total UCROM for each device is provided in Table 1. Data for reliability is presented in Table 2 for inter-phone/examiner and intra-phone/examiner. A MANOVA was performed to determine if there was a difference in UCROM measurements by sex. Analysis reveals that males had significantly greater left, right and total UCROM as compared to females using either phone ($p < 0.001$).

DISCUSSION

This is the first published study to measure UCROM using both IP and AN smartphone technology coupled with an inclinometer application. The data demonstrated that UCROM can be reliably measured using these devices in a laboratory setting. The reliability measures for between phone and within phone measures were high (ICC >0.81) and are consistent with those found in other studies examining the reliability of smartphone coupled with various applications to measure total cervical range of motion.[9,10] This study and previous published reports demonstrate that smartphone technology can reliably measure both total cervical range of motion and UCROM.[9,10] The results of this current study suggests that smartphones, using the Clinometer app, can be utilized to reliably measure UCROM.

This study found that in non-symptomatic male and female subjects, of college age, there was significantly, $p < 0.001$, greater left, right and total UCROM in males as compared to females. There appears to be a gap in the literature reporting differences in UCROM differences in males versus females. Ogince et al.[6] noted males had greater UCROM than females, however, this difference was not statistically significant in a population of subjects with cervicogenic headache. The lack of statistical significance in the Ogince et al.'s[6] study may be due to the fact that their participants were symptomatic and placed in the supine position during measurements while our subjects where placed in sitting, healthy, without complaints of pain or stiffness and of collegiate age.

The modified flexion and rotation test has been shown to have a 91% diagnostic accuracy in identifying limitations in UCROM in subjects suffering from cervicogenic headache.[6] Ogince et al[6] relied on expert clinician judgment combined with manual measurement using a modified Cervical Range of Motion device to identify those with limited UCROM. The current study also relied upon expert clinician judgement to determine the end range of cervical rotation while performing the cervical flexion and rotation test in sitting, and was able to reveal similar data while concurrently measuring UCROM with smartphone inclinometry. The cost of the equipment used in this study, excluding the phones themselves, is less than $15. The current study demonstrated that clinicians can quickly and inexpensively measure UCROM reliably in their patients using a head strap and smart phone technology and commercially available inclinometer app.

CONCLUSION

Using a smartphone inclinometer app combined with an inexpensive camera mount can reliably measure UCROM in college age students.

References

1. Ernst MJ, Crawford RJ, Schelldorfer S, et al. Extension and flexion in the upper cervical spine in neck pain patients. *Manual therapy.* 2014.

2. Blanpied PR, Gross AR, Elliott JM, et al. Neck Pain: Revision 2017. *Journal of Orthopaedic & Sports Physical Therapy.* 2017;47(7):A1-A83.

3. Leddy JJ, Baker JG, Merchant A, et al. Brain or strain? Symptoms alone do not distinguish physiologic concussion from cervical/vestibular injury. *Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine.* 2015;25(3):237-242.

4. Endo K, Ichimaru K, Komagata M, Yamamoto K. Cervical vertigo and dizziness after whiplash injury. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society.* 2006;15(6):886-890.

5. Reneker JC, Clay Moughiman M, Cook CE. The diagnostic utility of clinical tests for differentiating between cervicogenic and other causes of dizziness after a sports-related concussion: An international Delphi study. *Journal of science and medicine in sport / Sports Medicine Australia.* 2015;18(4):366-372.

6. Ogince M, Hall T, Robinson K, Blackmore AM. The diagnostic validity of the cervical flexion–rotation test in C1/2-related cervicogenic headache. *Manual therapy.* 2007;12(3):256-262.

7. Hall T, Robinson K. The flexion–rotation test and active cervical mobility—A comparative measurement study in cervicogenic headache. *Manual therapy.* 2004;9(4):197-202.

8. Amiri M, Jull G, Bullock-Saxton J. Measuring range of active cervical rotation in a position of full head flexion using the 3D Fastrak measurement system: an intra-tester reliability study. *Manual therapy.* 2003;8(3):176-179.

9. Tousignant-Laflamme Y, Boutin N, Dion AM, Vallee C-A. Reliability and criterion validity of two applications of the iPhone[TM] to measure cervical range of motion in healthy participants. *Journal of NeuroEngineering and Rehabilitation.* 2013.

10. Wellmon RH, Guliek DT, Paterson ML, Guliek CN. Validity and Reliability of 2 Goniometrie Mobile Apps: Device, Application, and Examiner Factors. *Journal of Sport Rehabilitation.* 2016;25(4):371-379.

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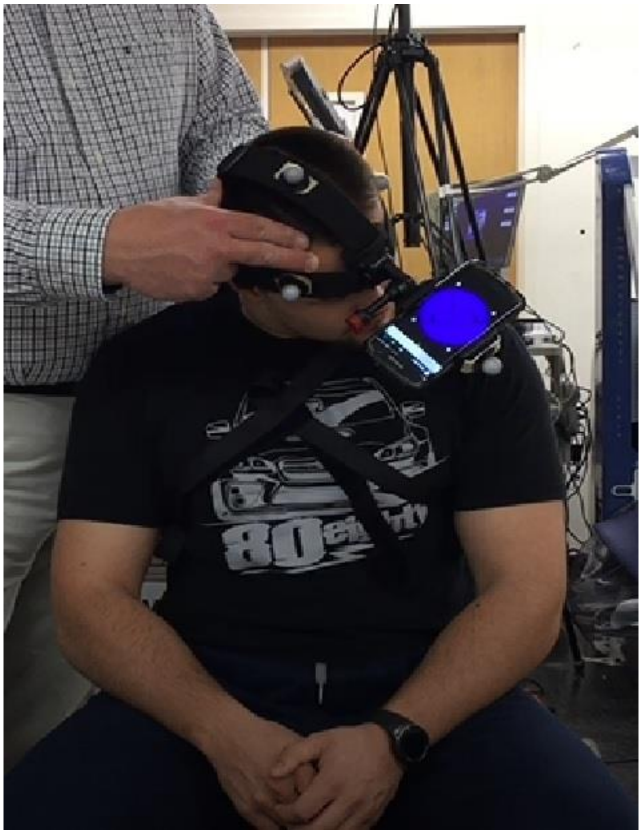

Figure 1: Testing Position

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Table 1: ROM Measurements

		Mean	Standard Deviation
I-Phone	Right Rotation	50.0	11.3
	Left Rotation	52.1	10.8
	Total ROM	102.1	21.0
Android	Right Rotation	47.4	6.6
	Left Rotation	47.6	9.0
	Total ROM	95.0	12.7

ROM: Range of Motion. Total ROM was calculated by adding mean left and right rotation together.

Table 2. Reliability table

			Confidence Interval		
		ICC	Upper	Lower	p
Inter-phone/examiner	Mean Peak ROM	0.872	0.786	0.928	< 0.001
	Mean Total ROM	0.817	0.575	0.914	< 0.001
Intra-phone/examiner	Android Left	0.962	0.936	0.979	< 0.001
	Android Right	0.912	0.849	0.951	< 0.001
	I-Phone Left	0.951	0.917	0.973	< 0.001
	I-Phone Right	0.979	0.964	0.988	< 0.001