The reliability of smartphone goniometry technology in measuring postural changes in South African female youths carrying head loads

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ABSTRACT

Background: Four empirical studies have measured the impact of head-loading on female African porters' posture using expensive radiography and manual kinanthropometry and goniometry. The reliability of cheaper, pragmatic smartphone goniometric technology as an alternate clinical tool to assess posture is needed.

Objectives: This study was designed to test the inter-rater reliability of smartphone goniometry technology against manual goniometry in measuring selected sagittal postural angles in South African female youth who habitually head-load.

Methods: Female South African youth who habitually head-load voluntarily participated in the study (N = 100) and were randomly allocated into experimental (n = 50) and control (n = 50) groups. An observational randomised control design involving a pre-test post-test crossover was used, after which the control group crossed over into the experimental group and vice versa. The control group stood in the unloaded phase without a head load, while the experimental group carried the head load. The daily head loads and body mass were measured on an electronic scale. Demographic characteristics (age, body mass, and stature) were recorded and selected biomechanical angles were measured on the right side.

Results: The mean age of the study participants was 12.3 ± 2.5 years; average body mass was 44.5 ± 13.7 kg. The average head load habitually carried was 8.0 ± 2.5 kg. The inter-rater reliability between the smartphone goniometry technology and manual goniometry was 0.9.

Conclusion: The findings support the use of smartphone goniometry as a pragmatic method for assessing sagittal plane postural changes among rural South African youth who habitually head-load. Further studies are needed to validate these findings.

INTRODUCTION

The most popular mode of transporting food, water, and firewood in rural South African communities is through head-loading, as performed by young girls.[1] These loads are transported over distances of two to 10 km, and their mass varies from 3 to 35 kg.[2]

Empirical health research has revealed that habitual head-loading causes spondylolisthesis, intervertebral disc compression, and decreased standing vertex height, all of which adversely affect posture.[3-5] Measuring joint angles, using manual goniometry, is the traditional and validated method used to detect postural misalignment in clinical settings.[6] It involves physically measuring the angle created by two body segments, using a plastic goniometer. The method is easy, quick, and cost-effective, but is practitioner dependent. Radiographic and digital camera imaging were developed to eradicate the variance in manual goniometry testing among practitioners.

Radiographic imagery uses X-rays and/or gamma rays to examine the internal structure (skeletal alignment) to identify any flaws, defects and/or misalignment, thereby limiting measurement variance among practitioners. However, radiographic imagery is expensive and time consuming, and requires sophisticated equipment and trained practitioners. A practical limitation is the need for continuous supply of electricity, which can be a challenge in rural communities.

There is, thus, need for a cheap, reliable clinical postural goniometry screening tool that can be used in rural African communities. Camera imagery is a pragmatic method of assessing joint angles and has the benefit of being able to review the picture to determine the accuracy of the measurements. Smartphone technology allows for 1) the immediate analysis and transmission of primary digital imagery, 2) the digital imagery to be reviewed by an independent expert distant from the site, and 3) the subsequent confirmation of postural misalignments and prescription of therapeutic rehabilitation, where required. However, while the reliability of smartphone technology has been tested in controlled clinical environments,[7,8] it has not been tested in a non-clinical field setting.

The aim of this study was to compare reliability of smartphone goniometry technology with the manual goniometry method among female South African youth, when loading and unloading head loads.

METHODS

This was an observational randomised control study, involving a pre-test post-test crossover. The participants were randomly disseminated into the experimental (n = 50) and control (n = 50) groups by their personal selection of different-coloured balls from a hat, as described previously.[9,10] Thereafter, the control group crossed over into the experimental group and vice versa. This allowed both groups to be subjected to the same intervention, which was carrying their normal habitual head loads (Figure 1). The control group stood in the unloaded phase without a head load, while the experimental group carried the head load. The required sample size of 100 was calculated using the Cochran formula.

Head loads and body mass were measured using an electronic scale. Demographic data recorded were age, body mass, and height; biomechanical angles were measured on the right side of the body.

Three biomechanical angles, viz. the craniovertebral angle (CVA), the craniohorizontal angle (CHA), and the standing pelvic angle (SPA), which measures anterior pelvic tilt, were measured using manual goniometry and smartphone goniometry application technology (Huawei P30, smartphone application: Angulus). The smartphone was mounted onto a tripod 3 m away from the participant. The angles were measured in a private room by two female biokineticists in the presence of the participants' parents or guardians.

Manual goniometry biomechanical angles

The CVA and CHA were measured according to a protocol described by Chueng Lau et al. (2009)[11] (Figure 2). This required the tester to place the goniometer over the seventh cervical vertebra, aligning the stationary arm parallel to the ground, while the mobile arm was placed on the tragus of the right ear.[11] The CVA indicates the anterior translation of the cervical vertebrae in relation to the thorax. The CHA was measured by placing the centre of the goniometer on the tragus of the ear, with the stationary arm parallel to the ground, while the mobile arm was placed on the external canthus of the right eye (Figure 2).[11] The CHA indicates translation of the head to the cervical vertebrae in the sagittal plane. The SPA was measured according to a protocol described by Kim et al. (2009).[12]

Smartphone goniometry biomechanical angles

Using the smartphone application, the three angles were measured according to the same protocols used for the manual goniometry. Relevant anatomical sites were marked with small, coloured stickers, which served as points to which the smartphone goniometer was digitally aligned. The smartphone photographed the person's static posture, after which the smartphone goniometer was digitally placed on the picture and aligned with the anatomical reference points to measure the respective angles.

Ethical approval was secured from the Tshwane University of Technology (REC2020-12-001). iLembe Royal ethical consent was granted prior to the commencement of data collection. All participants habitually carried head loads and resided in the Glendale region of iLembe district in KwaZulu-Natal province.

Data analysis

Descriptive analyses included calculating means, standard deviations, and percentage changes in the three angles. Intra-class correlations were used to determine reliability of the smartphone goniometry technology compared to the manual goniometry. Paired t-tests determined if there were significant differences between the smartphone goniometry and manual goniometry measurements. Significance was set at 95%.

RESULTS

Young women aged nine to 17 years (mean 12.3 ± 2.5 years) voluntarily participated in the study. The mean body mass of the study participants was 44.5 ± 13.7 kg, mean height was 1.45 ± 0.1 m, and mean head load was 8.0 ± 2.5 kg (17.9% of the participants' mean body mass). The inter-rater reliability between smartphone goniometry technology and manual goniometry measurements was high for all measured angles (ICC = 0.99, Table 1). There were no statistically significant differences between the mean biomechanical angles in the head-loaded and unloaded phases when comparing smartphone goniometry and manual goniometry measurements (Table 1).

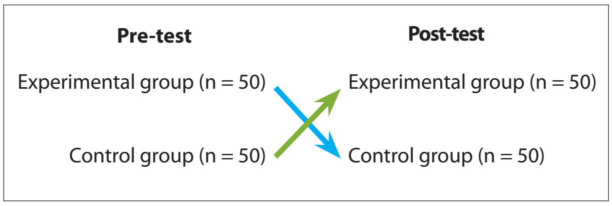

Figure 1. The observational randomised pre-test post-test crossover design of the study

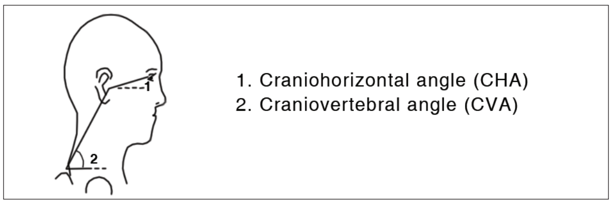

Figure 2. Depiction of craniohorizontal and craniovertebral angles

Table 1. Inter-rata reliability of manual versus smart phone goniometry

Measured angle (°)	Manual goniometry mean ± SD	Smart phone application mean ± SD	ICC	p value*
Unloaded CVA	13.730 ± 5.3	13.857 ± 5.2	0.99	0.482
Unloaded CHA	51.960 ± 6.9	52.142 ± 6.8	0.99	1.000
Unloaded SPA	17.950 ± 7.7	17.989 ± 7.8	0.99	0.740
Loaded CVA	19.430 ± 5.8	19.602 ± 5.6	0.99	0.095
Loaded CHA	54.540 ± 6.6	54.775 ± 6.4	0.99	0.842
Loaded SPA	20.520 ± 7.9	20.581 ± 8.0	0.99	0.469

*Paired t-test

DISCUSSION

This study was part of a larger research project that investigated the biomechanical and electromyographical impact of cranial loading porterage among children residing in the Glendale region (iLembe district) of KwaZulu-Natal province.[9,10]

Altered cervical angles, kyphosis, lordosis, and anterior pelvic tilts are postural screening elements that occupational therapists, physiotherapists, athletic trainers, and biokineticists routinely perform to identify serial distortion of the vertebral column in the sagittal plane.[6,13] The use of smartphone technology to capture and analyse postural screening results among international therapeutic rehabilitation specialists is growing.

This study is the first to compare manual goniometry with smartphone goniometry technology among participants in a rural non-clinical setting in South Africa. There was strong reliability between the manual and smartphone goniometry technology measurements, supporting findings from previous studies that were conducted in clinical settings.[7,8] Boland et al. (2016)[7] and Szucs and Brown (2018)[8] both reported high ICCs (0.71 and 0.81, respectively), although they were lower than those reported in our study. Boland et al. (2016) reviewed the inter- and intra-rater reliability of static posture analysis using a mobile phone application in a clinical controlled setting, with a small sample size of 10 participants (a major criticism of the study).[7] They reported strong intra- and inter-rater reliability between static postural analyses and mobile phone application.[7] Similarly, Szucs and Brown (2018) reported strong inter-rater reliability between smartphone goniometry and manual goniometry when assessing posture in a small sample of 20 participants, in a controlled clinical setting.[8]

The sample size in our study was 10 times larger than that in the Boland et al. study and five times larger than that in the Szucs and Brown study.[7,8] Small sample size reduces external validity, while larger sample size reduces the margin of error. Most statisticians agree that the minimum sample size to get a meaningful result is 100.[14] In randomised control trials involving experimental and control groups, it is recommended that a minimum of 30 participants be in each group. Our study met both criteria.

It is important to note that different smartphone brands and models, in combination with the various mobile phone goniometry applications, may lead to different results/findings. Therefore, different smartphone applications software should be validated and tested for reliability.

Recommendations

The reliability of smartphone goniometry technology should be tested as a diagnostic tool in the field. We assessed the reliability of static smartphone goniometry technology. A study using smartphone dynamic goniometry technology is needed to determine the reliability of porters' gait measurements, compared to biomechanical software such as Dart Fish and/or Quantarsalis. These biomechanical software tools generally require a clinical setting to identify biomechanical gait deviation. The application software is, however, very expensive and not conducive to field-work experimentation. Smartphone dynamic goniometry technology may be a cheaper and reliable alternative.

CONCLUSION

Our experimental study showed that smartphone goniometry technology is a pragmatic, user-friendly, and reliable tool to measure sagittal plane static posture. Most practitioners have smartphones and the goniometry application is free, reducing the cost of assessing posture. Smartphone goniometry technology is a reliable method for assessing changes in the sagittal plane or postural misalignment among rural South African youth who habitually head-load. Expensive radiographic equipment is scarce in rural communities. The use of smartphone technology will improve the quality of diagnostic and rehabilitation services in rural communities and potentially improve quality of life.

KEY MESSAGES

1. Smartphone goniometry technology is a reliable tool for measuring static sagittal posture.
2. Smartphone goniometry is an affordable tool that can be used in non-clinical rural settings.

DECLARATION

The authors declare that this is their own work; all the sources used in this paper have been duly acknowledged and there are no conflicts of interest.

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None received.

AUTHOR CONTRIBUTIONS

Conception and design of the study: MK, TJE
Data acquisition: MK, TJE, YP
Data analysis: MK, TJE
Interpretation of the data: MK, TJE
Drafting of the paper: MK, TJE, YP
Critical revision of the paper: TJE, MK, YP

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REFERENCES

1. Potgieter C-A, Pillay R, Rama S. Women, development and transport in rural Eastern Cape, South Africa. Cape Town: HSRC Press; 2006.
2. Kurten M, Motaung TG, Paul Y, Ellapen TJ. Cranial loading: the plight of the rural South African female. APhOT. 2020; 3(3). doi: 10.23880/aphot-16000172.
3. Echarri JJ, Forriol F. Effect of axial load on the cervical spine: a study of Congolese woodbearers. Int Orthop. 2002; 26(3):141-144. doi: 10.1007/s00264-002-0336-6.
4. Echarri JJ, Forriol F. Influence of the type of load on the cervical spine: a study on Congolese bearers. Spine J. 2005; 5:291-296. doi: 10.1016/j.spinee.2004.09.010.
5. Ellapen TJ, Abrahams S, Desai FA, Van Heerden HJ. Impact of habitual cranial loading on the vertebral column of adolescent African females aged 12–15 years in the Deepvale region of KwaZulu-Natal. AJPHERD. 2009; 15(4):690-700.
6. Prentice WE, editor. Rehabilitation Techniques for Sports Medicine and Athletic Training. 6th ed. Thorofare, NJ: SLACK Incorporated; 2015.
7. Boland DM, Neufeld EV, Ruddell J, Dolezal BA, Cooper CB. Inter- and intra-rater agreement of static posture analysis using a mobile application. J Phys Ther Sci. 2016; 28(12): 3398-3402. doi: 10.1589/jpts.28.3398.

8. Szucs KA, Brown EVD. Rater reliability and construct validity of a mobile application for posture analysis. J Phys Ther Sci. 2018; 30(1):31-36.
9. Kurten M. The biomechanical and electromyographical impact of cranial loading porterage among children residing in the Glendale, Ilembe District of KwaZulu-Natal. [unpublished master's thesis]. Pretoria: Tshwane University of Technology; 2021.
10. Kurten M, Ellapen TJ, Paul Y. The impact of cranial loading on sagittal plane posture, kinanthropometry and muscle activity of South African female youth. Occup Health Southern Afr. 2021; 27(5):159-163.
11. Cheung Lau HM, Wing Chiu TT, Lam T. Clinical measurement of craniovertebral angle by electronic head posture instrument: a test of reliability and validity. Man Ther. 2009; 14(4):363-368. doi: 10.1016/j.math.2008.05.004.
12. Kim W-J, Kang J-W, Kim H-Y, Sung H-I, Park K-Y, Park J-G, et al. Change of pelvic tilt before and after gait in patients with lumbar degenerative kyphosis. J Korean Soc Spine Surg. 2009; 16(2):95-103.
13. South Africa. Health Professions Act, 1974 (Act No. 56 of 1974). Regulations: Defining the scope of the profession of physiotherapy. Government Gazette No. 5349, 1976 December 3 (published under Government Notice R2301). Available from: https://www.hpcsa.co.za/Uploads/PPB/Rules%20and%20Regulations/regulations_gnr2301_76.pdf (accessed 24 Nov 2022).
14. Faber J, Fonseca LM. How sample size influences research outcomes. Dental Press J Orthod. 2014; 19(4):27-29. doi: 10.1590/2176-9451.19.4.027-029.