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Reliability and concurrent validity of knee angle measurement: Smart phone app versus universal goniometer used by experienced and novice clinicians

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ABSTRACT

The use of goniometers to measure joint angles is a key part of musculoskeletal practice. Recently smartphone goniometry applications have become available to clinicians.

This study examined the intra- and inter-measurer reliability of novice and experienced clinicians and the concurrent validity of assessing knee range of motion using a smartphone application (the Knee Goniometer App (Ockendon©)) (KGA) and a standard universal goniometer (UG).

Three clinicians, each with over seven years' experience as musculoskeletal physiotherapists and three final year physiotherapy students, measured 18 different knee joint angles three times, using both the universal goniometer and the smartphone goniometric application.

The universal goniometer and the smartphone goniometric application were reliable in repeated measures of knee flexion angles (average Concordance Correlation Coefficient (CCC) > 0.98) with both experienced clinicians and final year physiotherapy students (average CCCs > 0.96). There were no significant differences in reliability between the experienced and the novice practitioners for either device. Agreement between the universal goniometer and smartphone goniometric application measurements was also high for all examiners with average CCCs all above 0.96. The Standard Error of Measurement ranged between 1.56° (0.52–2.66) for the UG and 0.62° (0.29–1.27) for the KGA.

The universal goniometer and the smartphone goniometric application were reliable in repeated measures of knee flexion angles. Smaller error of measurement values for the smartphone goniometric application might indicate superiority for assessment where clinical situations demand greater precision of knee range of motion.

1. Introduction

Goniometry is an essential assessment skill in musculoskeletal practice, with the resultant measures used to determine the presence or absence of dysfunction, guide treatment interventions and generate evidence of treatment effectiveness (Gajdosik and Bohannon, 1987; Russell et al., 2003).

Universal goniometers (UG) are the most common form of goniometer used in clinical practice (Gajdosik and Bohannon, 1987; Russell et al., 2003). They are easily accessible, relatively inexpensive, portable and easy to use (Croxford et al., 1998). In recent years the advent of smartphones has brought a range of new technological applications (apps) within the reach of most consumers. Smartphones, cellular telephones with built-in applications and internet access, (PC Magazine [Internet]) run stand-alone operating system software that provide a platform for application developers (Phonescoop [Internet]). The low cost and user-friendly application interfaces have allowed consumers to access and utilise technologies which were un-imaginable a decade ago. A number of smartphone based goniometry apps are now available (Ferriero et al., 2013), with each app utilising a different mechanism for calculating joint angles.

With the increased call for accountability of health practitioners to third party funders of health services, and the increasing application of evidence based practice the use of formalised

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outcome measures has become an important part of clinical practice. Hence, the use of clinically valid and reliable measurement tools to assess joint Range of Motion (ROM) is an important consideration for therapists.

Reliability studies have shown that on repeated measures the UG demonstrated good overall intra- and inter-tester reliability (Brosseau et al., 2001). Whilst overall reliability of the UG has been reported as good, the reliability varies according to the joint and the range of movement (ROM) being measured (Rothstein et al., 1983).

The validity of UG measures for knee range of motion have been reported, using measures taken from radiographs as a reference standard (Brosseau et al., 1997). The correlation between universal goniometer measures and radiographs were reportedly higher for larger degrees of knee flexion (*Pearson product-moment correlation coefficient* $r = 0.73–0.77$) than for smaller degrees of knee flexion ($r = 0.33–0.41$) (Brosseau et al., 1997). Whilst used as a reference standard in some studies, issues associated with measuring joint angles from a radiograph, in particular procedural problems associated with the angle of the camera relative to the subject, (Gajdosik and Bohannon, 1987) indicate caution when interpreting and applying these results.

The reliability and validity of UG measures can be affected by incorrect application of the goniometer. Aspects such as the location of bony landmarks, the estimation of the centre of rotation of the joint and ability to locate and maintain the centre of the goniometer over this point, all require attention when using the UG (Gajdosik and Bohannon, 1987).

In an effort to improve the validity and reliability of the UG, various technologies have been applied to the development of alternative types of goniometers. Studies have examined the use of fluid based goniometers, (Rheault et al., 1988) parallelogram goniometers, (Brosseau et al., 1997) biaxial (Buchholz and Wellman, 1997) and triaxial, (Chao, 1980) electro-goniometers, computerised goniometers (Clapper and Wolf, 1988) and a digital goniometer (Carey et al., 2010). Whilst each form of goniometer has its own inherent benefits, issues such as cost and accessibility mean that the UG remains the equipment of choice for joint angle measurement for most musculoskeletal therapists. Due to the reported reliability and widespread use, a number of studies have used the UG as the reference standard for validating different goniometers (Brosseau et al., 1997, 2001).

One available smartphone goniometry app is the Knee Goniometer App (Ockendon©) (KGA). It is an accelerometer based knee goniometer, which measures tibial inclination and then calculates the knee flexion angle using a trigonometric equation. This system differs from other smartphone applications such as the DrGoniometer© which uses a virtual goniometer that is positioned on the smartphone screen on a photograph obtained using the smartphone camera (Ferriero et al., 2013).

The KGA requires a one-off calibration against any flat surface. A range of smartphone goniometer apps are available for other joints however the knee was chosen for this study as knee ROM is commonly measured in clinical practice, and has been most commonly used to examine reliability and validity of goniometric tools.

Whilst the KGA designers promote its use to eliminate the difficulties of palpating bony landmarks in the femoral segment, its development was based on certain assumptions; (a) morphologically typical adult patient (b) measurement in the horizontal supine posture and (c) predictable ratio of length femur to tibia (i.e. femur length 1.2 times tibial length) (Ockendon, 2012). The KGA developers fail to provide a definition of a 'morphologically typical adult patient'. No such assumptions exist for the use of the UG however appropriate anatomical knowledge, eye sight and manual dexterity of the examiner are assumed.

Recent evidence indicates high levels of intra-examiner reliability when measuring maximal knee flexion in healthy participants using the KGA, (Hambly et al., 2012) however no information is available regarding inter-examiner reliability, especially with respect to the clinical experience of the measurer.

The authors of this study observed that the use of smartphone based goniometer apps, such as the KGA, were becoming increasingly popular amongst undergraduate and new graduate physiotherapists. As the results of goniometric measurements are often used to make decisions on clinical management strategies, which may affect the patient's physical, financial, social and psychological well-being, all new instruments designed to measure ROM should be tested thoroughly before use in the clinical setting. Issues such as the intra- and inter-tester reliability of the tool are important as clinical decisions are often based on repeated measures by the same or by different therapists (Phonescoop [Internet]). Errors associated with the use of a goniometer can arise from the tool, the tester or from variability in the performance of the individual (Piriyaprasarth and Morris, 2004).

The purpose of this study was

a) To determine the reproducibility (both intra-tester and inter-tester reliability) of the UG and the KGA for measuring knee ROM.
b) To determine the concurrent validity of the KGA, using the UG as the reference standard.
c) To identify if reliability and concurrent validity values for measurement of knee ROM using a universal goniometer or KGA were altered by the level of experience of the therapists (i.e. observer variability bias).

We hypothesised that there would be agreement between repeated measures of knee ROM when using the UG and the KGA and that the inter-tester and intra-tester reliability of these two instruments would be high.

2. Method

Ethics approval for the study was obtained from the James Cook University Human Research ethics committee (Ethics approval no: H4062).

2.1. Participants

2.1.1. Examiners

Goniometric measurement was performed by three final year students enrolled in the Bachelor of Physiotherapy and three qualified physiotherapists with at least seven years orthopaedic clinical experience, and experience with the use of the UG. None of the students or qualified practitioners had any experience using the KGA. The students had extensive experience with the use of the UG in their undergraduate training.

2.1.2. Subjects to be measured (measurees)

Measurees for this study were six healthy student volunteers (three men and three women) attending James Cook University, Townsville campus. The right knee was selected for measurement. The measurees were screened by self-report questionnaire, and had no history of musculoskeletal or neurological injury to the lower limb. Each measuree signed an informed consent form prior to participation.

As the aim of the project was to study the reliability of the KGA and UG measurements by different examiners in a normal healthy population there was no attempt to identify if the measurees met the KGA developers assumptions.