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Original research

Reliability and measurement precision of concentric-to-isometric and eccentric-to-isometric knee active joint position sense tests in uninjured physically active adults

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ABSTRACT

Objectives: Proprioception is important because it is used by the central nervous system to mediate muscle control of joint stability, posture, and movement. Knee active joint position sense (AJPS) is one representation of knee proprioception. The purpose of this study was to establish the intra-tester, inter-session, test–retest reliability of concentric-to-isometric (seated knee extension; prone knee flexion) and eccentric-to-isometric (seated knee flexion; prone knee extension) knee AJPS tests in uninjured adults.
Design: Descriptive.
Setting: University laboratory.
Participants: Six males, six females (age 26.2 ± 5.7 years; height 171.1 ± 9.6 cm; mass 71.1 ± 16.6 kg).
Main Outcome Measures: Mean absolute error (AE; °); intraclass correlation coefficient (ICC) (2,1); standard error of measurement (SEM; °).
Results: Mean AE ranged from 3.18° to 5.97° across tests. The ICCs and SEMs were: seated knee extension 0.13, 1.3°; prone knee flexion 0.51, 1.2°; seated knee flexion 0.31, 1.7°; prone knee extension 0.87, 1.4°.
Conclusions: The prone knee flexion and prone knee extension tests demonstrated moderate to good reliability. Prone knee flexion and prone knee extension AJPS tests may be useful in cross-sectional studies estimating how proprioception contributes to knee functional joint stability or prospective studies estimating the role of proprioception in the onset of knee injury.

1. Introduction

Proprioception is defined as the sense of joint position (joint position sense (JPS)) and joint movement (kinesthesia) (Martin & Jessell, 1991; Riemann & Lephart, 2002), and results from mechanoreceptor stimulation in joint and muscle tissues (Kandel, 2013; Martin & Jessell, 1991). Proprioceptive input to the central nervous system (CNS) influences muscle activity at all three levels of sensorimotor control (spinal cord, brainstem, cerebral cortex), and is used by the CNS to mediate skeletal muscle control of joint stability, posture, and movement (Ghez, 1991; Lephart, Pincivero, Giraldo, & Fu, 1997). With regard to the knee, injury can result in destruction of mechanoreceptors (Bali, Dhillon, Vasistha, Kakkar, Chana, & Prabhakar, 2012). Loss of mechanoreceptors after knee injury is associated with impaired joint-muscle reflexes and abnormal movement patterns (Beard, Kyberd, O'Connor, Fergusson, & Dodd, 1994; Houck, De Haven, & Maloney, 2007; Wojtys & Huston, 1994). Consequently, authors have described how impaired proprioception is a potential contributing factor to first-time joint injury, repetitive joint injury, and the onset and progression of osteoarthrosis (OA) (Borsa, Sauers, & Lephart, 1999; Felson et al., 2009; Hurley, 1997; Roos, Herzog, Block, & Bennell, 2011; Segal

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et al., 2010). Therefore, because impaired proprioception is described as resulting in a potentially greater risk of joint trauma and subsequent OA, measurement of knee proprioception is clinically important.

Proprioception measurements can be performed under passive and active conditions, corresponding to where skeletal muscle is inactive and active, respectively. Passive conditions preferentially stimulate joint mechanoreceptors whereas active conditions assess both joint and muscle-tendon mechanoreceptors (Riemann, Myers, & Lephart, 2002). Researchers have employed different operational definitions as methods for studying the multi-component construct of knee proprioception. For example, knee JPS tests have included passive reproduction of passive positioning (PRPP) (Callaghan, Selfe, Bagley, & Oldham, 2002; Callaghan, Selfe, McHenry, & Oldham, 2008; Perlau, Frank, & Fick, 1995), active reproduction of passive positioning (ARPP) (Baker, Bennell, Stillman, Cowan, & Crossley, 2002; Bennell, Wee, Crossley, Stillman, & Hodges, 2005; Fridén, Roberts, Zätterström, Lindstrand, & Moritz, 1996), and active reproduction of active positioning (active JPS (AJPS)) (Callaghan et al., 2002; Callaghan et al., 2008; Drouin, Houglum, Perrin, & Gansneder, 2003). Knee kinesthesia tests have included threshold to detection of passive motion (TTDPM) (Barrack, Skinner, & Buckley, 1989; Borsa, Lephart, Irrgang, Safran, & Fu, 1997; Callaghan et al., 2002). Because tests such as PRPP and TTDPM are performed under conditions where muscle is relaxed, this may explain why passive tests are not strongly associated with measures of knee functional joint stability (e.g. hop tests) (Ageberg & Fridén, 2008; Borsa et al., 1997; Fridén, Roberts, Movin, & Wredmark, 1998) or the onset and progression of knee OA (Felson et al., 2009; Hurley, Scott, Rees, & Newham, 1997; Knoop et al., 2011). Passive tests may not be sufficiently functional because they do not stimulate the muscle spindle which is the most sensitive of all mechanoreceptors (Gordon & Ghez, 1991; Rothwell, 1994). Active tests for measuring proprioception may offer a better representation of the construct of knee proprioception under more functional conditions.

Active tests of knee proprioception can employ a variety of different muscle actions. Active tests such as ARPP and AJPS have been performed using concentric-to-isometric quadriceps muscle actions from a defined starting position (e.g. 90° knee flexion) to a predetermined target angle (e.g. 45° knee flexion) (Callaghan et al., 2002; Felson et al., 2009; Hurley et al., 1997), and concentric-to-isometric hamstrings muscle actions also from a defined starting position (e.g. 0° knee flexion) to a predetermined target angle (e.g. 45° knee flexion) (Ghiasi & Akbari, 2007). Concentric-to-isometric tests clearly do not employ eccentric muscle actions which generate the most powerful stimulus for the muscle spindle and are employed when decelerating joint motion and absorbing joint impact forces (Gordon & Ghez, 1991; LaStayo, Woolf, Lewek, Snyder-Mackler, Reich, & Lindstedt, 2003; Rothwell, 1994). Eccentric-to-isometric deceleration of high-velocity knee joint motions is important for limiting excessive joint displacements and preventing traumatic tissue injury (LaStayo et al., 2003). Eccentric-to-isometric absorption of repetitive knee joint impact forces (energy) during walking and running is important for protecting articular surfaces from cumulative shock that can contribute to the onset and progression of joint degeneration (OA) (Lewek, Rudolph, Axe, & Snyder-Mackler, 2002). Few authors have studied AJPS using eccentric-to-isometric quadriceps muscle actions (Drouin et al., 2003), and there appears to be no published reports using eccentric-to-isometric hamstrings muscle actions. Furthermore, recent reviews have concluded that existing tests of knee proprioception are inadequate and lacking in clinical relevance (Gokeler et al., 2011; Knoop et al., 2011). Cross-sectional studies report weak associations between existing tests of knee proprioception and knee functional joint stability defined by single-leg hop test performance (Gokeler et al., 2011). Prospective studies report no association between existing tests of knee proprioception and future onset of knee degeneration defined by x-ray evidence of OA (Knoop et al., 2011). Therefore, existing tests of knee proprioception appear to be failing with regards to usefully characterising proprioception relative to short-term measures of knee functional joint stability, as well as long-term imaging measures of tibiofemoral articular surface integrity which may be important relative to the onset of post-injury secondary OA. New tests of knee proprioception should, consequently, be developed for use in research and clinical practice.

For a new test of knee proprioception to have clinical relevance, researchers and clinicians need to be confident the test yields a meaningful representation of the underlying physiological characteristic. Reliability is a foundation property for measurement procedures, and refers to the ability of a test to generate repeatable and consistent values (Portney & Watkins, 2009). Reliability is a critical prerequisite for measurement validity (Batterham & George, 2003; Portney & Watkins, 2009). Lack of reliability can undermine the validity of raw data and compromise the findings of subsequent statistical modelling. Therefore, before the clinical relevance of a knee proprioception test can be determined, the reliability of the test must first be established. This is the first step in any future research process intended to obtain a cross-sectional estimate regarding the role of proprioception in, for example, knee functional joint stability in uninjured athletes or to prospectively identify the role of knee proprioception in the onset of noncontact trauma or post-injury secondary OA.

The purpose of this study was to establish the intra-tester, inter-session, test–retest reliability of concentric-to-isometric and eccentric-to-isometric knee AJPS tests in uninjured physically active adults. Tests were designed to stimulate muscle proprioceptive apparatus over a range of muscle actions by deliberately exploiting alpha–gamma coactivation and excitation of muscle spindles, along with stimulation of Golgi tendon organs which are specifically sensitive to changes in active muscle tension (Gordon & Ghez, 1991; Rothwell, 1994). Eccentric muscle actions generate the most powerful stimulus for the muscle spindle and are critical for decelerating joint motion (Gordon & Ghez, 1991; LaStayo et al., 2003; Rothwell, 1994). Eccentric-to-isometric tests were specifically intended, therefore, to focus mechanical stimuli on the muscle spindle and simulate the natural sequence of muscle actions observed within neuromuscular strategies for limiting excessive joint displacements (eccentric-to-isometric). We hypothesised that tests would demonstrate good reliability using the intraclass correlation coefficient (ICC) as recommended by previous researchers (Atkinson & Nevill, 1998; Denegar & Ball, 1993). This study's findings have the potential to fill the first and most important gap in information regarding the reliability of new knee proprioception tests.

2. Methods

2.1. Sample size calculation

An *a priori* power analysis for ICC was performed using PASS 11 (NCSS Statistical Software, Utah). Twelve participants were required to achieve 82% power and detect an ICC of 0.90 with significance set at 0.05. To account for possible participant attrition or technical problems, two additional participants were recruited. A total of 14 participants were enrolled.