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Original article

Regional asymmetry, obesity and gender determines tactile acuity of the knee regions: A cross-sectional study☆

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ABSTRACT

Background and aims: Alterations in central somatosensory function (e.g. cortical reorganisation) occurs secondary to chronic knee pain. The reorganization can be quantified using a clinical signatory measure, the two-point discrimination threshold (TPDT). In order to differentiate normal variability of TPDT against abnormal thresholds for clinical practice, development of body region specific reference values are required and the factors that determine the TPDT have to be established.
Objective: To establish reference values for TPDT of the knee region in healthy individuals and to determine the factors that influence the TPDT of the knee regions.
Methods: Participants across four decades (18–59 years; n = 79) were recruited. TPDT estimates for medial and lateral knee regions were determined using a mechanical calliper. Descriptive statistics, and linear regression analyses were performed to establish reference TPDT values, and to investigate associations between demographics, anthropometric variables, and TPDT estimates respectively.
Results: Participants' Mean (SD) age = 38.3 (12.2); females (n = 56); and right lower limb dominant (n = 72). Mean TPDT threshold ranges included: lateral right knee, 36.7 (14.3); medial right knee, 28.6 (9.7); lateral left knee, 37.7 (12.9); and medial left knee, 27.9 (11.4). Fifteen percent of the threshold variance ($R2 = 0.148$) of TPDT estimates was explained by the medial aspect ($\beta = -8.9$; $p = 0.000$) and male gender ($\beta = 3.1$; $p = 0.057$), weighted by anthropometric factors.
Conclusions: Age-stratified knee TPDT estimates have been reported to aid clinical interpretation. Regional asymmetry, gender, and obesity indices are factors that determine the TPDT of the knee. Normal TPDT asymmetry observed at medial aspect of the knee has significantly greater acuity compared to the lateral knee.

1. Introduction

Knee pain is a common musculoskeletal disorder encountered in clinical practice, contributing to 17.1 million years of life lived with disability among the world-wide population in 2010 (Woolf and Pfleger, 2003; Cross et al., 2014). A range of pathophysiological manifestations affecting the intra-articular, peri-articular, and extra-articular structures include degenerative, inflammatory, and mechanical processes which may contribute to joint pain (Sokolove and Lepus, 2013). Considering the mismatch between medical imaging findings and clinical signs and symptoms, the etiological mechanisms behind joint pain could be partly explained by central neurological adaptive mechanisms (Staud, 2011). These adaptive mechanisms occur secondary to chronic peripheral nociceptive activity at the receptor, dorsal horn, cortical and sub-cortical areas where the sensory information is processed for perception of pain (Haigh et al., 2003; Arendt-Nielsen et al., 2010; Allen, 2011; Murphy et al., 2012; Lluch et al., 2014).

Chronic nociceptive inputs associated with musculoskeletal conditions are associated with changes to the anatomical representation of the sensory and motor cortices of a specific body region (Wand et al., 2011; Catley et al., 2014). The changes in the cortices are observed in individuals with chronic low back pain, chronic knee pain (knee osteoarthritis), complex regional pain syndromes, and limb amputations (Flor et al., 1997; Grüsser et al., 2001; Pleger et al., 2006; Shanahan et al., 2015). The structural changes in the brain, known as cortical reorganization, adapt to the chronic nociceptive inputs (Flor et al., 1997). Cortical

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reorganisation is generally quantified by using various electrophysiological and brain imaging techniques for research purposes (Flor et al., 1997; Grüsser et al., 2001; Gwilym et al., 2010; Shanahan et al., 2015). However, clinically feasible methods to quantify such adaptive cortical processes secondary to chronic nociceptive inputs for early intervention is minimal. Recent research suggests that the extent of the cortical representation of a body region can be quantified by assessing the magnitude of two-point discrimination threshold (TPDT) of that body region using a mechanical caliper tool (Moseley, 2008; Moseley et al., 2008; Catley et al., 2013).

Two-point discrimination describes a function of touch that has significant peripheral and cortical neural mechanisms and it is a measure of tactile acuity. Traditionally, the TPDT is used as a measure of cutaneous innervation density (i.e. receptive field size) (Lundborg and Rosen, 2004), which can be influenced by sensory ageing (Koltzenburg et al., 1999; Wickremaratchi and Llewelyn, 2006; Decorps et al., 2014), anthropometric factors including body mass index (BMI) (Falling and Mani, 2016) and body fat ratios (Boles and Givens, 2011), and dermatomal organization (Horner and Dellon, 1994). Recent meta-analysis suggests that there is an increased TPDT in individuals with musculoskeletal pain including chronic knee pain (Catley et al., 2014), where the peripheral nervous system organization is unaltered. This indicates the ability of TPDT to identify altered central somatosensory function in chronic musculoskeletal pain, thereby the TPDT has expanded its clinical utility beyond investigating the integrity of peripheral nerve function (Tamura et al., 2003; Maihöfner and DeCol, 2007).

Recent evidence that investigated the TPDT of the knee joint found significant differences in TPDT in a small, non-age stratified clinical population (chronic knee pain) compared against healthy controls (Stanton et al., 2012, 2013). This evidence clearly articulates the need for clinical assessment of altered central somatosensory function (e.g. cortical reorganization, warranting the need to embrace interventions targeting such adaptive central processes associated with chronic knee pain (Moseley and Flor, 2012)). However, the statistically significant difference in TPDT estimates was not adjusted for common variables that may have positively or negatively confounded the observed differences. A range of demographic and anthropometric factors and the potential interactions among these factors can influence the sensory acuity of the body region. Literature (Nolan, 1983; Bell-Krotoski et al., 1993; Bowden and McNulty, 2013; Catley et al., 2013) addresses the contribution of demographic (age, gender, side, limb dominance) and anthropometric factors on TPDT estimates in regions of high acuity, however, the underlying mechanisms are not completely understood for regions of lower acuity (e.g knee regions). There is a definitive lack of understanding of how these factors may influence the TPDT over peripheral joints, including knee joints. Establishing an improved understanding of those factors may help inform how one (clinicians/researchers) can normalize cortical representation through targeted interventions designed to address modifiable factors (Moseley and Flor, 2012).

A large body of evidence has established TPDT reference values for areas of high functional acuity, including those of the hand and face (Nolan, 1985; Posnick et al., 1990; Bell-Krotoski et al., 1993). However, only few studies have investigated TPDT over joint regions which are the commonly encountered in musculoskeletal clinical practice (Nolan, 1983; Catley et al., 2013). In addition, for clinical practice, normal reference values are needed in order to help clinicians differentiate normal variability of TPDT against abnormal thresholds in symptomatic populations. To the best of our knowledge, no previous studies have developed reference TPDT values or examined the determinants of knee joint organization. Evidence suggests that sensory deficits exist in the contralateral uninjured side, mediated through several mechanisms including altered central neuronal activity (Donaldson, 1999; Koltzenburg et al., 1999; Shenker et al., 2003; Kelly et al., 2007). This suggests the need for establishing reference values for both knee joints which will help clinicians to differentiate from normal against the abnormal thresholds when assessing for altered central somatosensory function in patients with unilateral or bilateral joint pain. Therefore, the aims of this study are to develop age-stratified TPDT reference values for knee (side and regions), and to investigate the associations of demographic (age, gender, body side, knee regions) and anthropometric variables (body mass index (BMI) and waist-height ratio (WHR)) on TPDT (a measure of tactile acuity).

2. Methods

2.1. Study design

This study is a part of the larger cross-sectional research that investigated TPDT estimates of the low back regions (Falling and Mani, 2016). This study was granted ethical approval by the University of X Human Ethics Committee. Written consent to participate in the study was obtained from all participants. TPDT was measured at four sites for each participant, including: medial and lateral regions of both knees. Each site was assessed once, in random testing order generated and counterbalanced by a web based sequencer (https://www.random.org/). Duration of testing for each participant was approximately 20 min.

2.2. Participants

Healthy adults between the age group 18–59 years were recruited using convenience sampling technique. Study participants were primarily recruited through email invitations to staff and students of the University of X. The participants were recruited across four decades (i.e. 18–30; 31–40; 40–50; 51–60 years). Participants were excluded if they reported: current pain and/or past history (within the last two years) of pain in the legs that was sufficient to restrict activity; surgery within the last two years; skin conditions; neurological conditions including peripheral nerve injuries and neuropathy; diabetes mellitus; attention and cognitive disorders; and pregnancy (including less than six months post-partum).

2.3. Pilot testing

Pilot testing was performed on healthy individuals ($n = 4$) in order for the assessor to become familiarized and consistent with the testing procedure. The testing procedure components were reported in the previously published study by the research team (Falling et al., 2015; Falling and Mani, 2016).

2.4. Procedure

Anthropometric data (height, weight, waist and hip circumference) were collected from each participant, according to American College of Sports Medicine recommendations (ACSM, 2013). In addition, participant's age, gender, ethnicity, and lower limb dominance (Schneiders et al., 2010) were collected.

2.4.1. Test area and positioning

For TPDT assessment of knee regions, participants were positioned in supine with full knee extension for testing of the medial region, and in side-lying with approximately 10 degrees of knee flexion for testing of the lateral region. Bilateral knee assessments