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Original article

Tactile acuity, body schema integrity and physical performance of the shoulder: A cross-sectional study☆

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ABSTRACT

Background: Normative two-point discrimination thresholds (TPDTs) have been reported for different body regions and the relationships between TPDT and body schema integrity and physical performances are previously shown. However, such relationships with shoulder physical performance have not been investigated.
Objectives: To quantify TPDT of the shoulders in healthy individuals and investigate whether TPDT and body schema integrity are related to physical performances and to identify the relationship between TPDT and body schema integrity.
Design: Cross-sectional study.
Results: Means (SD) of TPDTs of the dominant shoulder (DS) and non-dominant shoulder (NDS) were 44.8 (13.1) mm and 39.3 (9.5) mm respectively. TPDT scores were significantly negatively correlated with closed kinetic chain upper extremity stability test (CKCUEST) scores ($r = -385$, $p = .036$) and left/right judgement task (LRJT) response times (DS: rho = −449, p = .013 and NDS: rho = −388, p = .034). No significant correlations were found between TPDT and scores on functional throwing performance index (FTPI) and LRJT accuracy. However, positive moderate correlations were observed between LRJT and CKCUEST scores.
Conclusions: TPDTs for ND and NDS in a cohort of adults have been documented. Tactile acuity and body schema integrity scores were correlated with superior performance in the upper limb stability task, indicating the potential role of tactile acuity and motor imagery training on maximizing physical performance.

1. Introduction

Shoulder pain is a highly prevalent and disabling condition among general and sporting populations (Picavet and Schouten, 2003; McBeth and Jones, 2007; May et al., 2010). The traditional view on the aetiology of shoulder pain has largely emphasized the anatomical structures capable of producing nociceptive inputs when damaged or positioned under repetitive stress (Dean et al., 2013). Recently, the need to include additional explanatory models in the assessment and treatment of shoulder pain has been highlighted (Littlewood et al., 2013; Struyf et al., 2015). This is based on emerging radiological evidence of pathological changes in a large proportion of healthy individuals (Connor et al., 2003; Yamamoto et al., 2011), in addition to a mismatch between the magnitude of pain and the extent of local tissue pathology (Littlewood et al., 2013; Struyf et al., 2015).

This clinical paradox raises the need to investigate central pain mechanisms currently highlighted as potential factors contributing to shoulder pain which may also serve as promising targets for treatment (Moseley and Flor, 2012; Pelletier et al., 2015). Examples of studied mal-adaptive central pain mechanisms include dorsal horn disinhibition, dysfunctional conditioned pain modulation, and maladaptive structural reorganisation in the brain (Lotze and Moseley, 2007; Pelletier et al., 2015). Among the maladaptive structural changes, reorganisation of body region specific representation in the primary somatosensory cortex (S1) has been identified in different chronic pain populations (Flor et al., 1997; Juottonen et al., 2002; Pleger et al., 2006). Increased two-point discrimination threshold (TPDT) of a body region has been shown to correlate with the extent of S1 cortical reorganisation (Flor et al.,

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1997). TPDT is a measure of tactile acuity and it can be hypothesized as a proxy measure and/or a clinical marker of such cortical changes (Pleger et al., 2006; Lotze and Moseley, 2007; Catley et al., 2013). A recent review concluded that TPDTs are larger for patients suffering from a range of chronic pain conditions compared to controls (Catley et al., 2014). More importantly, larger TPDTs are generally confined to the area of pain (Catley et al., 2014). This research evidence corroborates maladaptive cortical reorganisation as a feature of chronic pain which warrants further investigation of normative TPDT values in healthy individuals and in those with shoulder pain.

Cortical reorganisation of S1 is also hypothesised as a likely contributor to motor disturbances. Recent evidence has identified a correlation between TPDT and movement control both in neck and low back pain patients (Luomajoki and Moseley, 2011; Elsig et al., 2014). It is well known that the motor and sensory cortices are functionally linked, but how these maps eventually work together to form our perception of the body and the execution of motor function, i.e. physical performance (PP), is less understood (Lotze and Moseley, 2007). One suggested link between these areas is the “body schema”, explained as the internal map which the brain uses for movement (Bray and Moseley, 2011; Moseley and Flor, 2012). Since the integrity of the body schema depends on sensory input from S1, a disruption in sensory maps would also be likely to influence the proprioceptive abilities of that region (Bray and Moseley, 2011; Luomajoki and Moseley, 2011). The integrity of the body schema can be indirectly measured with a timed implicit motor imagery task such as the left/right judgement task (LRJT) (Bray and Moseley, 2011; Moseley and Flor, 2012). A substantial amount of work has shown that to make a judgement about which side of the body a pictured body part belongs to, a mental rotation of the body part and a comparison to an internal map is required, thus suggesting that reduced accuracy reflects a disruption in the body schema (Parsons and Fox, 1998; Bray and Moseley, 2011; Moseley and Flor, 2012).

To gain more insight into these areas and their application in clinical situations, an understanding of these parameters (TPDT, LRJT and PP) in isolation and their inter-relationships in healthy individuals is essential. An understanding of what is ‘normal’ will further guide clinical practice and research towards identifying ways to influence these inter-related regions in order to optimise shoulder function and reduce pain. On examining the literature, studies which quantify differences between dominant and non-dominant shoulder and regions within a shoulder, or investigate relationships in either healthy or symptomatic individuals were not identified. Therefore, this study first aimed to quantify TPDTs on the dominant shoulder (DS) and the non-dominant shoulder (NDS). Using this acquired data, the study also aimed to investigate the cross-sectional relationships between TPDT, and LRJT and PP in healthy adults.

Considering that the extent of S1 representation is use-dependent (Ragert et al., 2004; Gindrat et al., 2015) and that a larger TPDT correlates to poorer performance on a stability task (Luomajoki and Moseley, 2011), we hypothesize that tactile acuity will be better on the dominant versus the non-dominant shoulder (i.e., smaller TPDT on the dominant side) and that better tactile acuity will correlate with body schema integrity measurers (LRJT accuracy scores and response times). Furthermore, we hypothesize that better body schema integrity and better tactile acuity (i.e. smaller TPDT) will correlate to better PP scores.

2. Methods

2.1. Study design and ethical approval

A cross-sectional study of healthy adults (aged 18–40 years) was conducted in a University setting. The ethical approval was obtained from the University of Otago Human Ethics Committee (Health).

2.2. Participants

All participants filled in a health screening form and signed a consent form. A convenience sample of the first 30 eligible subjects who responded to study advertisement was recruited. Exclusion criteria were: history of shoulder pain in the previous two years sufficient to restrict work or leisure for more than two days, current history of pain in upper limb, upper back or neck, history of neurological disease, any medical condition that affects sensation or attention, cognitive disorders, and pregnancy.

2.3. Pilot testing

An overview of the testing protocol is presented in Table 1. In order to standardise the testing protocol (experimental setup, instructions, feedback and testing procedure), the physiotherapist (tester) carried out pilot testing on healthy individuals ($n = 5$), prior to data collection.

2.4. Data collection

All participants filled in demographic information, the short form laterality questionnaire to determine handedness (Veale, 2014), and the previously validated shoulder activity scale (Brophy et al., 2005; Hepper et al., 2013). Anthropometric (height, weight, total upper limb and upper arm length, upper arm circumference, and triceps skin fold) measurements were recorded according to standard practice guidelines (Gordon et al., 1988). Initially, all participants underwent assessment of TPDT of DS and

Table 1
Testing procedure.

	TPDT[a]	CKCUEST[b]	FTPI[b]	LRJT[b]
Practice	Familiarisation with and testing of light touch	Single practice trial (~15 s)	Single practice trial (~30 s)	Single practice trial (30 images in “Vanilla” category; ~2 min)
Testing	Non-dominant shoulder (lateral region) Dominant shoulder (anterior, lateral and posterior regions) 1 min rest period between the regions of testing	3 × 15 s. 45 s rest between	3 × 30 s testing 45 s rest between	3 × 50 images in “contextual” category
Time, approximate per participant	~20 min	~5 min	~7 min	~7 min

CKCUEST – closed kinetic chain upper extremity stability test; FTPI – functional throwing performance index; LRJT – left/right judgement task (recognise shoulder®); TPDT – two-point discrimination threshold.
[a] Block randomisation of testing order between dominant and non-dominant shoulders and regions within the dominant shoulder.
[b] Order of testing was randomised in blocks.