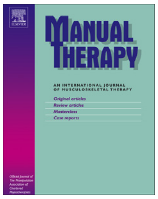
Manual Therapy 20 (2015) 166–170

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math



Original article

The effect of experimentally-induced subacromial pain on proprioception

Gisela Sole [a, *], Hamish Osborne [b], Craig Wassinger [c]

[a] Centre for Health, Activity and Rehabilitation Research, University of Otago, New Zealand
[b] School of Medicine, University of Otago, New Zealand
[c] Department of Physical Therapy, East Tennessee State University, USA

ARTICLE INFO

Article history:
Received 5 March 2014
Received in revised form
2 August 2014
Accepted 26 August 2014

Keywords:
Experimental pain
Shoulder
Kinaesthesia
Proprioception

ABSTRACT

Shoulder injuries may be associated with proprioceptive deficits, however, it is unknown whether these changes are due to the experience of pain, tissue damage, or a combination of these. The aim of this study was to investigate the effect of experimentally-induced sub-acromial pain on proprioceptive variables. Sub-acromial pain was induced via hypertonic saline injection in 20 healthy participants. Passive joint replication (PJR) and threshold to detection of movement direction (TTDMD) were assessed with a Biodex System 3 Pro isokinetic dynamometer for baseline control, experimental pain and recovery control conditions with a starting position of 60° shoulder abduction. The target angle for PJR was 60° external rotation, starting from 40°. TTDMD was tested from a position of 20° external rotation. Repeated measures ANOVAs were used to determine differences between PJR absolute and variable errors and TTDMD for the control and experimental conditions. Pain was elicited with a median 7 on the Numeric Pain Rating Scale. TTDMD was significantly decreased for the experimental pain condition compared to baseline and recovery conditions (≈30%, $P = 0.003$). No significant differences were found for absolute ($P = 0.152$) and variable ($P = 0.514$) error for PJR. Movement sense was enhanced for the experimental sub-acromial pain condition, which may reflect protective effects of the central nervous system in response to the pain. Where decreased passive proprioception is observed in shoulders with injuries, these may be due to a combination of peripheral tissue injury and neural adaptations that differ from those due to acute pain.

1. Introduction

The glenohumeral joint relies heavily on the dynamic action of muscles for stability during activities of daily living and occupation- and sports-related tasks (Myers and Oyama, 2008). Afferent sensory or proprioceptive information from capsuloligamentous mechanoreceptors, muscle spindles, visual and cutaneous sensors is integrated by the central nervous system to modify neuromuscular control systems to provide stability and optimize performance (Myers and Oyama, 2008; Fortier and Basset, 2012). Proprioception is generally divided into four domains, kinaesthesia (joint position sense or replication, and movement sense), sense of tension, sense of effort and the sense of balance (Fortier and Basset, 2012). Kinaesthesia is frequently used related to shoulder injury and is recorded using the active or passive joint replication (AJR or PJR), and 'threshold to detection of passive movement direction' (TTDMD), respectively (Fortier and Basset, 2012).

The sensorimotor system has been investigated extensively relative to shoulder injuries and it is generally accepted that injuries result in impaired proprioception of the glenohumeral joint due to damage of mechanoreceptors and changes in the neural pathways (Myers and Oyama, 2008; Fortier and Basset, 2012). There is evidence for decreased kinaesthesia of the shoulder in participants with shoulder dislocations (Lephart et al., 1994) or instability (Barden et al., 2004). Patients with chronic sub-acromial pain (Machner et al., 2003) and rotator cuff injury (Anderson and Wee, 2011) have also been shown to have reduced shoulder proprioception compared to uninjured controls. Furthermore, impaired proprioception has been investigated as a dependent variable to determine efficacy of treatment interventions. For example, shoulder joint position sense and TTDMD were found to be restored after surgery for patients with recurrent anterior instability (Lephart et al., 1994; Rokito et al., 2010). For healthy

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* Corresponding author. Centre for Health, Activity and Rehabilitation Research, University of Otago, Box 56, Dunedin 9054, New Zealand. Tel.: +64 3 4797936; fax: +64 3 4798414.
E-mail address: gisela.sole@otago.ac.nz (G. Sole).

http://dx.doi.org/10.1016/j.math.2014.08.009
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individuals, no significant difference was found for joint position sense after application of cryotherapy (Wassinger et al., 2007), while proprioception decreased (based on increased TTDMD) following fatiguing exercise for the shoulder (Carpenter et al., 1998). Overhand athletes were shown to have increased TTDMD in the dominant versus non-dominant shoulders in a starting position of 75° external rotation in 90° abduction, but not in neutral (Allegrucci et al., 1995). Similarly, female baseball pitchers had decreased position sense compared to non-players, and those authors suggested that the decreased proprioception may predispose those athletes to injury (Dover et al., 2003).

Although impaired proprioception has been described for patients with shoulder pain, the mechanisms whereby this happens is unclear. It has been suggested that changes in proprioception are likely to be due to both tissue damage and pain mechanisms (Myers and Oyama, 2008). However, to date, the relationship between shoulder injury and proprioceptive deficit remains elusive and it is not clear whether these deficits develop as a result of, or contribute, towards injury, or whether they are affected by symptoms, such as pain. While longitudinal studies would be needed to investigate such possible relationships, experimental pain models allow assessment of the influence of pain when administered to individuals without tissue injury, such as injecting hypertonic saline into muscle or periarticular structures, creating transient local or referred pain (Olesen et al., 2012). It has been postulated that pain interferes with perception of limb position (Hellstrom et al., 2000), however, experimentally-induced pain in the soleus and gastrocnemius muscles did not affect ankle joint position sense, while impairing movement sense (with increased detection of movement thresholds) (Matre et al., 2002). No such studies, to our knowledge, have been performed to investigate the effects of experimental shoulder pain on kinaesthesia.

We have recently used an experimental-induced pain model to investigate effects of acute shoulder pain on external and internal shoulder rotation strength, throwing accuracy (Wassinger et al., 2012), scapula movement (Wassinger et al., 2013) and electromyographic activity of shoulder muscles (Sole et al., 2014). While there are various etiological origins for shoulder disorders in athletes, a large proportion of these injuries involve the subacromial structures (subacromial bursa, rotator cuff) as possible sources of symptoms for pain and functional disability. The aim of this study was to investigate the effect of experimentally-induced sub-acromial pain on proprioceptive variables (joint movement and position sense) at the shoulder. It was hypothesised that participants will demonstrate decreased proprioceptive function while experiencing experimentally-induced sub-acromial pain (SAP) compared to the control condition. Specifically, TTDMD and passive joint replication (PJR) will demonstrate increased error scores for the experimental pain condition compared to the control condition.

2. Materials and methods

Twenty healthy participants were recruited from a University community and volunteered to participate in the study (Table 1). The participants were free of shoulder pain in the past 6 months and none had a history of seeking medical care for shoulder or neck injury at any time. All testing was completed in a University research laboratory using procedures approved by the University of Otago Human Ethics Committee and all participants provided written informed consent in accordance with institutional guidelines. Anthropometric measurements (height, weight) and hand dominance, determined as the arm the participants would use to throw a ball, were recorded. Only one participant was left-side dominant.

Table 1
Subjects demographics.

	N	Age (y)	Height (m)	Weight (kg)
Male	10	22.3 (5.7)	1.78 (0.08)	75.8 (11.8)
Female	10	20.4 (1.1)	1.64 (0.05)	61.5 (5.3)
Total	20	23.0 (4.8)	1.72 (0.09)	70.0 (11.1)

A repeated measures design was used with three conditions: a baseline control condition followed by the experimental pain condition, and finally the recovery control condition (Diederichsen et al., 2009). The participant rested until pain was reduced to “zero” on an 11-point Numerical Pain Rating Scale (NPRS) following the experimental pain condition, before proceeding with the recovery control condition.

Measures for PJR and TTDMD were collected using the Biodex System 3 Pro isokinetic dynamometer (Biodex Medical INC, Shirley, NY) and Research Tool Kit software application. All participants were instructed on the procedures and given several practice repetitions using the device prior to data collection. All testing was completed on the dominant shoulder. For each condition (baseline control, experimental pain, and recovery control), PJR was performed first, followed by TTDMD.

For PJR, the starting position was upright sitting with the shoulder in 60° abduction in the scapular plane, confirmed with a handheld inclinometer (Industrial Research Limited, Christchurch, New Zealand). Pelvic and torso straps were used to minimize the trunk movements and the participant was blindfolded. The opposite arm was kept in a constant position, with the hand resting on the ipsilateral thigh. The starting position for the shoulder was 40° external rotation and the target angle was 60°. This position as chosen as it was considered that the intensity of pain for the experimental condition may be excessive towards the end of range of movement (such as in the 90th percentile, as recommended by Janwantanakul et al. (2001)). The arm was placed into a pneumatic sleeve (Kinetic Corporation Inc. Houston, TX) inflated with 25 mm of Hg pressure to normalize cutaneous sensation. The participant's arm was moved passively from the starting position towards the target angle at 5°/s angular velocity and held in this position for 10 s. On returning to the starting position the machine moved the testing arm toward the target angle at the same velocity. Participants were asked to press the ‘stop button’ when they felt that they had reached the target angle. Three measurements were performed and the angular error was noted to calculate the constant and the variable errors. The absolute and variable errors were calculated. The absolute error is the absolute (unsigned) difference between the target and the perceived angles, representing error irrespective of direction (Appendix 1). Variable error is the consistency of the performer and was calculated using the equation in Appendix 1. A high variable error indicates that the performance is inconsistent, whereas a low variable error implies that the scores are very similar (van Beers et al., 1996; O'Sullivan et al., 2013). Test-retest reliability (with 30 participants) for absolute PJR in our laboratory found an Intraclass Correlation Coefficient (ICC, and 95% confidence interval, CI) of 0.79 (0.56–0.90) with a standard error of measurement (SEM) of 0.98° for the absolute angular error.

For assessment of TTDMD, participants were blindfolded and wore headphones playing ‘white noise’ to eliminate visual and auditory clues (Fig. 1). The starting position for the shoulder was 60° abduction in the scapular plane, 20° external rotation from neutral, defined as the horizontal position for the forearm, as determined with the handheld inclinometer. After familiarization the test was started within a random gap of 5–15 s. Passive shoulder internal rotation or external rotation were performed at a constant angular velocity of 0.5°/s. Participants were instructed to press the stop button as soon as shoulder movement and the direction of movement were perceived. Six trials, three in each