Relationship of knee joint proprioception to pain and disability in individuals with knee osteoarthritis

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Abstract

Proprioception plays an integral role in neuromotor control of the knee joint and deficits in knee joint proprioception are well documented in individuals with knee osteoarthritis (OA). However, the functional relevance of these deficits is not clear. This cross-sectional study evaluated the relationship between knee joint proprioception and pain and disability in a large cohort of individuals with knee OA. Two hundred and twenty participants (145 F, 75 M) with symptomatic knee OA were recruited from the community. Five non-weight bearing active tests with ipsilateral limb matching responses were performed at 20° and 40° flexion to measure knee joint position sense. Pain and disability were assessed by self-reported questionnaires and objective measures of balance and gait. Results showed little association between knee joint position sense variables and measures of pain and disability (r values ~0.24, most p > 0.05). When comparing participants with the worst and best joint position sense, no significant differences in pain and disability could be found (p > 0.05). While our study design does not allow causality to be established, these results suggest that deficits in joint position sense may be due to factors other than pain and that deficits are not large enough to impact upon disability.

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Keywords: Knee; Osteoarthritis; Proprioception; Pain; Disability

Introduction

Osteoarthritis (OA) is one of the most common musculoskeletal complaints worldwide [2,4,32]. It is characterised by pain, disability and progressive loss of function and is associated with significant health and welfare costs [34]. The knee is the most frequently affected joint of the lower limb. As prevalence of knee OA increases with age [13,14], the overall burden of the disease is expected to increase given the ageing of the population [3].

Patients with knee OA report pain and difficulty with functional activities such as prolonged sitting, ascending and descending stairs, walking, squatting, kneeling, rising from a chair and getting in and out of a car [12,18,29]. Ultimately these limitations lead to a loss of functional independence and reduced quality of life. Physical function depends upon many physiological parameters including muscle strength, sensory input from proprioception, visual and vestibular systems, intact balance mechanisms, range of motion and higher cortical function. Impairments in these parameters are likely contributors to disability.

Neuromotor control of the knee involves the co-ordinated activity of surrounding muscles in particular, the quadriceps. This co-ordinated activity provides active stability to the knee joint thus assisting in the absorption of much of the load placed on the knee joint during weight-bearing activities [26,42]. Knee joint proprioception is essential to neuromotor control. Proprioceptive afferent information from mechanoreceptors in the muscles, ligaments, capsule, menisci, and skin
of OA was graded by a radiologist according to the Kellgren and Lawrence system [30]. The severity of OA was rated as Grade 1 in 33 (15%) individuals, Grade 2 in 24 (10.9%), Grade 3 in 133 (60.5%) and Grade 4 in 23 (10.5%) individuals. Patellofemoral joint narrowing was detected in 72 (32.7%) individuals while patellofemoral joint osteophytes were detected in 170 (77.3%) individuals.

The study was approved by the University of Melbourne Human Research Ethics Committee. All participants provided written informed consent.

Methods

Participants

Two hundred and twenty participants (145 female, 75 male) with knee OA and aged over 50 years were recruited by advertisements in local clubs, libraries, and the print and radio media. These participants were part of two cohorts recruited for randomised, controlled trials of physiotherapy interventions. Diagnosis of OA was confirmed by a rheumatologist based on the American College of Rheumatology clinical and radiological classification criteria [1]. Participants with OA were included if they had knee pain on most days of the previous month (average level >3 cm on a 10 cm visual analogue scale (VAS)), demonstrated osteophytes on X-ray, and experienced pain and/or difficulty on getting up from sitting or climbing stairs. All participants were independent in activities of daily living and had a stable intake of non-steroidal anti-inflammatory drugs over the previous fortnight. Exclusion criteria included physiotherapy treatment for the knee (previous 12 months), knee surgery (previous three months), past history of lower limb joint replacement, Synvisc® or intra-articular steroid injection (previous six months), systemic arthritic condition, or history of lower limb joint replacement, Synvisc® or intra-articular steroid injection (previous six months), systemic arthritic condition, or severe medical condition precluding safe testing.

The mean age, height, weight and body mass index (BMI) of the group was 68.6 (8.3) yr, 1.64 (0.09) m, 79.1 (12.9) kg and 29.3 (4.2) kg/m² respectively. Participants had experienced knee symptoms for 9.1 (9.3) yr. One hundred and thirteen (51.6%) individuals reported unilateral symptoms and 107 (48.6%) reported bilateral symptoms.

Participants had X-rays (skyline, weightbearing antero-posterior and lateral) of the tested knee within the previous 12 months. Severity of OA was graded by a radiologist according to the Kellgren and Lawrence system [30]. The severity of OA was rated as Grade 1 in 33 (15%) individuals, Grade 2 in 24 (10.9%), Grade 3 in 133 (60.5%) and Grade 4 in 23 (10.5%) individuals. Patellofemoral joint narrowing was detected in 72 (32.7%) individuals while patellofemoral joint osteophytes were detected in 170 (77.3%) individuals.

The study was approved by the University of Melbourne Human Research Ethics Committee. All participants provided written informed consent.

Procedure

The affected limb (or most symptomatic in case of bilateral symptoms) was tested. The dominant leg was tested in 118 (53.6%) individuals.

Self reported knee pain and disability

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [8] is a disease-specific questionnaire that evaluates knee pain and disability. The questionnaire uses a series of five-point Likert scales to evaluate the dimensions of pain and physical function. Aggregate scores are obtained for each dimension by summing the component item scores.

Ten-cm horizontal VAS [25], marked in lcm increments, recorded average pain on movement and activity restriction over the previous week and severity of pain experienced during knee joint position sense testing.

Step test

The step test is a functional, dynamic test of standing balance [22]. Participants were instructed to maintain balance on the symptomatic leg whilst stepping the contralateral limb on and off a 15 cm step as quickly as possible. The number of times the participant could place the foot up onto the step and return it to the floor over a 15-s interval was recorded. Participants performed the test with bare feet and with no hand support. The test was performed once only, with 2-3 practice steps permitted prior to the test. If loss of balance occurred, the test was ceased and the number of completed steps up until this point recorded.

Tinnet up and go (TUG)

A stop watch was used to time the participant rising from a standard arm chair, walking to a line on the floor 3 m away, turning around, returning to the chair and sitting down again [43]. The participant was bare-footed and was asked to perform the task at his/her own pace. An explanation and demonstration was provided by the investigator but no practice trials were given. The test was performed once.

Walking speed

Walking gait was analysed at a self-selected fast pace on a level surface as this has been shown to be more reliable than normal pace [16]. Participants walked in their own shoes along a 7.5 m walkway. Custom-made timing gates with infrared sensors attached to a stop watch were used to determine the time taken to walk the middle 2.5 m. Speed was calculated by dividing the distance walked by the time taken and recorded in m/s. Results were averaged over five trials.

Knee joint position sense

Knee JPS was examined in non-weightbearing using an established protocol [48,49]. Participants were seated on a treatment couch with knees flexed and the trunk supported. Reflective skin markers were used to determine knee joint angles and were attached to designated landmarks. The landmarks were the apex of the greater trochanter, the iliotibial tract (at the superior border of the patella), neck of fibula and lateral malleolus. With the participant’s eyes closed the investigator lightly grasped the foot and passively extended the relaxed knee from the resting position (approximately 80° flexion) to one of two test positions approximately 20° and 40° flexion. The participant was instructed to hold the knee in the test position for 3 s and to concentrate on ‘sensing’ the knee position. The investigator then returned the relaxed limb to the resting position. The participant was then instructed to extend the knee to the perceived test position and to hold that position for 3 s. Each test position was examined five times each. Movement data were recorded using a single camera.

The angle of the knee in each test and match position was determined using computer analysis of videotape images and the two-dimensional automatic digitising module of the peak measurement system (Peak Motus [43-31]. Peak Performance Technologies Incorporated, Englewood, USA). A segment of videotape showing each position was automatically digitised for 0.48 s at a frequency of 50 Hz. The obtained raw data representing the spatial location of the four reference markers were then filtered using a robust non-linear least-squares fourth order (Butterworth) filter (Peak Performance Technologies, 1995).

contribute at the spinal level to arthrokinetic and muscular reflexes which play a large part in dynamic joint stability [27,28,33]. The information is also conveyed to supraspinal centres [23] where it is integral to motor learning and the on-going programming of complex movements.

Compared to similarly aged asymptomatic individuals, deficits in knee joint proprioceptive acuity are well documented in patients with knee OA [6,7,20,31,41]. Given the important role of proprioception in neuro-motor control of the knee joint, it may be hypothesised that proprioceptive impairment contributes to the pain and disability associated with the disease. However, few studies have investigated this relationship within individuals with knee OA. While some authors have demonstrated a link between proprioceptive impairment and either physical function [35,36,41,47] or pain [41] in individuals with OA, others have failed to do so [20,24,46,47].

Thus, the aim of this study was to further evaluate the relationship between knee joint proprioception and pain and disability in a large cohort of individuals with symptomatic knee OA. Knowledge of this relationship would assist in developing targeted interventions to alleviate symptoms in the osteoarthritic population.
Three dependent variables were calculated (i) relative error—this was defined as the mean arithmetic difference between the five test and response positions. Relative errors represent accuracy with directional bias; (ii) absolute error—this was determined as the mean difference between the five test and response positions without reference to whether it constituted under- or over-estimation and (iii) variable error—this was defined as the standard deviation from the mean of each set of five relative errors. Variable errors represent the ability of the subjects to consistently sense each set of test positions.

The reliability of this method of measurement was established in five individuals tested on two occasions one week apart. The results demonstrated excellent test retest reliability with intraclass correlation coefficients (ICC) ranging from 0.86 to 0.94 with the exception of variable error at 20 where the ICC was lower at 0.44.

Data analysis

The relationship between the three knee JPS variables at 20° and 40° of knee flexion and pain and disability measures were evaluated in the entire cohort using Spearman’s correlation coefficients. The cohort was then divided into sub-groups based on tertiles of absolute error at 20° and then on tertiles of absolute error at 40°. The measures of pain and disability were then compared between the lowest (least absolute error) and highest (greatest absolute error) tertiles using independent t tests. To reduce the risk of making a Type I error with multiple tests, the significance level was set at \( p < 0.01 \).

Results

Mean (SD) values for pain, disability and JPS are shown in Table 1. The results of the correlations between the JPS variables and the measures of pain and function in the entire cohort are shown in Table 2. Of the 48 correlations tested, only three reached statistical significance. The strength of these relationships was weak, with \( r \) values less than \( r = 0.24 \) indicating that less than 5% of the variation in the JPS variable could be explained by the pain or disability measure.

When comparing participants with the worst and best JPS, as indicated by absolute error, no significant differences in measures of pain or disability were found (Tables 3 and 4).

Discussion

The results of this study showed that knee joint position sense, measured by active ipsilateral joint matching, was not associated with pain or disability in a large cohort of individuals with symptomatic knee OA. Furthermore, no differences in pain and disability could be found comparing those with ‘best’ and those with ‘worst’ JPS as measured by the amount of absolute error.

Relationship between proprioception and pain

Experimentally induced pain models have indicated that pain may influence the proprioceptive system [9,21]. Simplistically, chemical substances produced during the pain response may sensitise free nerve endings resulting in abnormal discharge of pain afferents. Via influences of gamma-motorneurones, muscle spindle afferent activity may be altered thus interfering with proprioceptive input [9,21,28,45].

However, the relationship between pain and proprioception is complex with human studies failing to find a clear link between the two. Matre et al. [38] used

### Table 1

Mean (SD) and range of pain, disability and knee joint position sense variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS—movement pain (cm)</td>
<td>5 (2)</td>
<td>2-10</td>
</tr>
<tr>
<td>VAS—JPS test pain (cm)</td>
<td>2 (2)</td>
<td>0-9</td>
</tr>
<tr>
<td>WOMAC—pain (0-20)</td>
<td>8 (3)</td>
<td>2-17</td>
</tr>
<tr>
<td>Disability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAS—restriction (cm)</td>
<td>5 (2)</td>
<td>0-10</td>
</tr>
<tr>
<td>WOMAC—PF (0-68)</td>
<td>29 (10)</td>
<td>7-54</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>12.5 (3.5)</td>
<td>7.6-31.9</td>
</tr>
<tr>
<td>Step test (s)</td>
<td>11 (3)</td>
<td>2.22</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>1.3 (0.3)</td>
<td>0.4-2.1</td>
</tr>
<tr>
<td>JPS (°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative error 20°</td>
<td>1.3 (2.0)</td>
<td>-6.6 to 7.6</td>
</tr>
<tr>
<td>Absolute error 20°</td>
<td>2.3 (1.3)</td>
<td>0.4-7.6</td>
</tr>
<tr>
<td>Variable error 20°</td>
<td>1.9 (0.9)</td>
<td>1.0-6.4</td>
</tr>
<tr>
<td>Relative error 40°</td>
<td>2.6 (2.0)</td>
<td>-2.3 to 9.4</td>
</tr>
<tr>
<td>Absolute error 40°</td>
<td>3.2 (1.5)</td>
<td>0.7-9.4</td>
</tr>
<tr>
<td>Variable error 40°</td>
<td>2.4 (1.0)</td>
<td>0.5-5.6</td>
</tr>
</tbody>
</table>

### Table 2

Correlation coefficients for the relationship between knee joint position sense and pain and disability in individuals with knee OA

<table>
<thead>
<tr>
<th>Pain and disability</th>
<th>Relative error 20°</th>
<th>Absolute error 20°</th>
<th>Variable error 20°</th>
<th>Relative error 40°</th>
<th>Absolute error 40°</th>
<th>Variable error 40°</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS—pain</td>
<td>0.11</td>
<td>-0.05</td>
<td>-0.06</td>
<td>0.07</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>VAS—JPS test pain</td>
<td>0.08</td>
<td>-0.03</td>
<td>-0.10</td>
<td>-0.03</td>
<td>0.02</td>
<td>0.23</td>
</tr>
<tr>
<td>WOMAC—pain</td>
<td>-0.02</td>
<td>-0.10</td>
<td>-0.14</td>
<td>0.16</td>
<td>0.12</td>
<td>0.11</td>
</tr>
<tr>
<td>VAS restriction</td>
<td>-0.06</td>
<td>-0.05</td>
<td>-0.08</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>WOMAC—PF</td>
<td>-0.07</td>
<td>-0.09</td>
<td>-0.11</td>
<td>0.15</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>TUG</td>
<td>-0.19</td>
<td>0.05</td>
<td>-0.02</td>
<td>0.01</td>
<td>0.07</td>
<td>0.16</td>
</tr>
<tr>
<td>Step</td>
<td>0.10</td>
<td>0.08</td>
<td>0.06</td>
<td>-0.01</td>
<td>-0.03</td>
<td>-0.07</td>
</tr>
<tr>
<td>Walking speed</td>
<td>0.19</td>
<td>0.08</td>
<td>0.05</td>
<td>0.001</td>
<td>-0.60</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

PF = physical function.

* \( p < 0.01 \).
Recent studies have indicated that human ankle proprioception is relatively robust to muscle pain. To our knowledge, only four previous studies have examined the relationship between pain and proprioception in patients with knee OA [19,41,46,47]. Of these, only one found a significant relationship between parameters. However, the strength of the relationship was weak with pain explaining only 19% of the variation in proprioceptive acuity [41]. In contrast, Sharma et al. [46] and Skinner et al. [47] found no relationship in small cohorts. With our large sample size of 220 and inclusion of multiple measures of pain and joint position sense, our findings lend greater support to these non-significant results. Recent studies have suggested that proprioceptive deficits and disability might be expected. However, there are conflicting findings about this relationship in individuals with knee joint OA. Some studies have reported poorer proprioception in those with greater disability as assessed by the WOMAC physical function score [41]. Lequesne Index score [35], stair climbing time [36] and walking speed [47]. Conversely, other studies using similar measures of disability but with much larger sample sizes have reported no relationship with proprioception [20,24]. Unlike previous studies, we included a battery of both self-reported and objective disability measures. This, combined with our large cohort, leads us to conclude that joint position sense deficits are not significantly associated with disability in knee OA.

The lack of association observed between proprioceptive acuity and disability in knee OA may relate to the magnitude of proprioceptive deficits. Though errors in knee joint position sense are significantly higher than in asymptomatic elderly [6,17,20,37], the size of the deficit does not appear large enough to impact on clinical disability measures. It may be that a certain threshold of proprioceptive deficit is required before physical function is affected.

Disability in patients with knee OA is multi-factorial. It is likely that factors apart from proprioceptive deficit play a greater role in influencing the degree of disability [11,39,44,50,51]. Severity of pain is a consistent predictor of disability together with psychological factors including pain coping, helplessness, anxiety and well-being. Patient-related characteristics such as age and obesity are also important. While radiological disease severity has generally not been shown to predict disability, physical factors particularly quadriceps strength and joint range of motion are significant determinants.

### Table 3
Mean (SD) of pain and disability comparing those with least absolute error at 20° and those with most absolute error

<table>
<thead>
<tr>
<th></th>
<th>Least absolute error, 20° (N = 70)</th>
<th>Most absolute error, 20° (N = 70)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS—pain (cm)</td>
<td>6 (2)</td>
<td>5 (2)</td>
</tr>
<tr>
<td>VAD—JPS test pain (cm)</td>
<td>2 (2)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>WOMAC—pain (0-20)</td>
<td>9 (3)</td>
<td>8 (3)</td>
</tr>
<tr>
<td>VAS—restriction (cm)</td>
<td>5 (2)</td>
<td>5 (2)</td>
</tr>
<tr>
<td>WOMAC—PF (0-68)</td>
<td>32 (9)</td>
<td>28 (11)</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>13.0 (3.7)</td>
<td>12.6 (3.4)</td>
</tr>
<tr>
<td>Step (m)</td>
<td>11 (4)</td>
<td>11 (3)</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>1.3 (0.2)</td>
<td>1.3 (0.3)</td>
</tr>
</tbody>
</table>

**PF = physical function.**

### Table 4
Mean (SD) of pain and disability comparing those with least absolute error at 40° and those with most absolute error

<table>
<thead>
<tr>
<th></th>
<th>Least absolute error, 40° (N = 71)</th>
<th>Most absolute error, 40° (N = 74)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS—pain (cm)</td>
<td>5 (2)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>VAS—JPS test pain (cm)</td>
<td>3 (3)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>WOMAC—pain (0-20)</td>
<td>8 (3)</td>
<td>9 (3)</td>
</tr>
<tr>
<td>VAS—restriction (cm)</td>
<td>5 (2)</td>
<td>5 (2)</td>
</tr>
<tr>
<td>WOMAC—PF (0-68)</td>
<td>27 (9)</td>
<td>29 (11)</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>12.5 (3.5)</td>
<td>12.6 (3.6)</td>
</tr>
<tr>
<td>Step (m)</td>
<td>11 (3)</td>
<td>11 (3)</td>
</tr>
<tr>
<td>Walking speed (m/s)</td>
<td>1.3 (0.2)</td>
<td>1.3 (0.3)</td>
</tr>
</tbody>
</table>
Our study revealed no association between proprioception and pain or disability in individuals with knee OA. Overall, our method of measuring knee JPS is highly reproducible and is sensitive enough to discriminate between groups with and without knee pathology [5]. Thus it is unlikely that our null findings are due to an unreliable measurement technique. There is no gold standard for assessing proprioceptive acuity. While measurement of joint position sense using accuracy of reproduction tests is a common method, particularly in the OA literature, threshold of detection tests have also been utilised [6,31]. As these latter tests assess different aspects of proprioception, a relationship between these and pain and disability cannot be excluded. Thus, a possible explanation for our lack of relationship may be our choice of proprioceptive test. Finally, our study evaluated the relationship between a unilateral knee-specific measure (JPS) with global disability measures that largely assess bilateral lower limb function. Although deficits in knee JPS may be present in the tested limb, it is feasible that the unaffected (or less affected) limb may compensate or mask the influence of these deficits on pain and disability. While a cross-sectional study does not allow causality to be established, our results might suggest that strategies designed to address proprioceptive deficits may not impact upon either pain or disability.

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References


