Concise Report

Effect of experimentally induced knee pain on standing balance in healthy older individuals

K. L. Bennell and R. S. Hinman

Objective. Standing balance is impaired in older individuals with knee pain. The extent to which this impairment is due to the effects of pain itself or other pathophysiological aspects related to the underlying musculoskeletal condition causing the pain is unclear. To isolate the influence of pain, this study evaluated the effect of experimentally induced knee pain on standing balance in healthy older individuals.

Methods. We used a repeated-measures, within-subject design involving 12 healthy individuals aged 50–60 yr and with no history of knee pathology. Balance was tested during two randomly allocated experimental conditions: (i) control and (ii) knee pain induced by injection of hypertonic saline into the infrapatellar fat pad. Balance was measured using a computerized force platform under static and dynamic conditions as well as via the functional step test.

Results. Standing balance was not significantly altered by experimentally induced acute knee pain, nor was there any relationship between the severity of reported pain and balance scores.

Conclusions. Impairments in balance associated with knee conditions such as osteoarthritis may be due to factors other than the sensation of pain. Thus, strategies designed to reduce pain in treatment of knee pathology may not necessarily lead to improvements in balance. Further research is required to determine the exact causes of balance impairment in individuals with knee joint pain and pathology.

Key Words: Knee joint, Balance, Nociception, Experimental pain, Hypertonic saline.

Balance is an integral component to most activities of daily living. Control of balance is dependent upon sensory input from the vestibular, visual and somatosensory systems. Central processing of this information results in coordinated neuromuscular responses which ensure that the centre of mass remains within the base of support. Effective control of balance thus relies not only on accurate sensory input but also on the timely response of strong muscles. Normal ageing is associated with a decline in the integrity of these physiological systems [1, 2]. In the elderly, impairments of balance have serious health implications. Poor balance is associated with an increased risk of falling [3], and fall-related injuries have significant individual and societal costs [4]. Balance impairments are also associated with poorer mobility measures in the elderly population [5].

Knee pain is experienced by around 30% of the elderly population [6, 7]. Whilst there are many potential causes of knee pain, osteoarthritis (OA) is a common cause in the elderly. Although balance deficits greater than those observed in similarly aged healthy controls are documented in patients with knee OA [8–11] the mechanisms behind observed balance deficits are poorly understood. In particular, the specific impact of knee pain itself on balance control is unclear. Knee pain could influence balance control via effects on proprioceptive input, central processing of information and efferent output to activate appropriate limb and trunk muscles [12, 13].

Several studies of knee OA have demonstrated a relationship between the severity of knee pain and balance [10, 11, 14], whereby greater knee pain is associated with poorer balance. However, alleviation of pain in such patients using an injection of bupivacaine into the knee joint does not improve postural sway [15]. It is difficult to isolate the specific effects of knee pain on balance in these studies due to the confounding influence of other factors associated with the underlying pathology such as structural changes within the joint, muscle weakness and proprioceptive impairment that exist over and above that observed with healthy ageing [16]. Furthermore, it is possible that patients may compensate for balance deficits caused by impairments in one or more of the physiological systems necessary for balance as a result of the OA process. For example, Jadelis et al. [14] found that knee OA patients with weak knee strength may still maintain high levels of balance by having strong ankles. Thus a method for accurately evaluating the specific effects of knee pain alone on balance is to use an experimentally induced pain model in asymptomatic controls.

The aim of this study was to induce pain in healthy older individuals to evaluate the effects of knee pain on standing balance. Injection of hypertonic saline is a well-accepted, efficient and safe method of inducing pain that rises rapidly to a maximum and subsides slowly, leaving no undesirable side-effects [17]. We have shown that hypertonic saline injected into the medial infrapatellar fat pad gives rise to pain of similar quality and distribution to that experienced in knee musculoskeletal conditions [18]. It was hypothesized that acute knee pain would impair performance in standing balance.

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Methods

Participants

Twelve healthy individuals (six females, six males) participated in the study. Individuals were excluded if they were aged less than 50 yr, reported any history of lower limb pathology or injury/pain in either knee for which treatment was sought or which interfered with function for more than 1 week over the past year, had a medical condition or were taking medication known to affect balance, reported a cold or ear infection within the previous month or had a history of dizzy spells, fainting episodes or light headedness.

The study was approved by the institutional Human Research Ethics Committee. All participants provided written informed consent and all procedures were conducted according to the Declaration of Helsinki.

Procedure

Participants performed the balance tests under two experimental conditions: (i) with no knee pain (control) and (ii) with knee pain experimentally induced by injection of hypertonic saline. The order of the experimental conditions was randomly assigned using a Latin square design. Balance tests within each experimental condition were also performed in a random order.

Sterile hypertonic saline (5%, 0.2–0.25 ml, Astra, Sweden) was injected into the medial infrapatellar fat pad region using a 25-gauge needle at an angle of 45° in a superolateral direction [18]. The needle was inserted to a depth of approximately 10 mm. Balance testing commenced once knee pain reached a severity level rated by the participant as ≥4 cm out of 10 cm on an 11-point numerical rating scale. If insufficient pain was experienced, a second injection was given.

Balance tests

Centre of pressure. A computerized force platform (Chattecx Balance System; Chattanooga Group Inc., TN, USA) was used to measure displacement of centre of pressure (COP) in mediolateral (ML) and anteroposterior (AP) directions under both static and dynamic testing conditions. The participant was instructed to remain as still as possible throughout testing. For dynamic conditions, angular perturbations were introduced. In these conditions, the footplates moved sinusoidally from horizontal to a tilt of 4° in (i) an ML direction and (ii) an AP direction in 8.33 s. Thus data were collected under three balance conditions: stable platform, ML tilting platform and AP tilting platform. The test order was randomized across participants.

All tests were conducted with eyes closed and involved a bilateral stance, with arms relaxed at the side. Data were collected over a 30 s interval and there was approximately 1 min rest between each test condition. A familiarization with each test condition occurred first, followed by the actual test approximately 5 min later.

The amplitude of COP displacement (cm) in the AP and the ML directions was the measurement obtained for each test condition. A higher score reflects greater unsteadiness. This method of assessing balance has excellent reliability [19].

Step test. The step test is a reliable functional, dynamic test of standing balance in older individuals [20]. Participants were instructed to maintain balance on the test 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 no hand support. The test was performed once only with two or three practice steps permitted prior to the test.

Pain measurements

During balance tests with experimentally induced pain, participants were asked to verbally indicate the severity of their pain using an 11-point numerical rating scale marked in 1 cm increments with the descriptors ‘no pain’ and ‘worst pain’ at either end.

Data analysis

Data were processed using SPSS (Norusis/SPSS Inc., Chicago, IL, USA). Data were examined for normality and homogeneity of variance prior to analysis. Either paired t-tests or Wilcoxon signed rank tests were used to compare balance scores obtained under the control and pain conditions. Correlation analyses between pain severity and change in balance scores (calculated as balance score with knee pain minus balance score under control condition) were conducted using either Pearson’s r or Spearman’s ρ. Values of P < 0.05 were regarded as statistically significant.

Results

The mean (s.d.) age, height, weight and body mass index of the participants was 55.5 (4.1) yr, 1.70 (0.1) m, 79.0 (15.3) kg and 27.3 (4.8) m/kg², respectively. The dominant leg was tested (defined as the leg used to kick a ball). This was the right leg in 83% (10/12) of participants.

Knee pain was successfully induced in all participants. Mean (s.d.) pain scores reported during the COP measures and the dynamic step test were 6.2 (1.5) cm and 5.8 (1.7) cm, respectively. Results of the centre of pressure balance tests are detailed in Table 1. In general, mean balance scores were higher in the pain condition than in the control condition, indicating increased unsteadiness. However, there were no significant differences across the conditions for any of the six measured variables. Balance responses to pain varied greatly between individuals with regard to both the magnitude and the direction of the response (an example is provided in Fig. 1). Analysis of the step test results also revealed no significant difference between conditions. The mean (s.d.) number of completed steps taken in the control condition was 17 (3) compared with 16 (3) in the pain condition.

There were no significant correlations between pain severity reported during the respective balance tests and changes in balance performance under the pain condition.

Discussion

This is the first study to evaluate the specific effects of experimentally induced knee pain on balance using healthy older individuals.

Table 1. Mean (s.d.) centre of pressure scores across each experimental condition and results of statistical comparisons

<table>
<thead>
<tr>
<th>Platform</th>
<th>Parameter</th>
<th>Condition</th>
<th>Control</th>
<th>Knee pain</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable</td>
<td>ML displacement (cm)</td>
<td>2.9 (0.9)</td>
<td>2.8 (1.2)</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AP displacement (cm)</td>
<td>3.2 (0.9)</td>
<td>4.3 (2.1)</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>AP tilt</td>
<td>ML displacement (cm)</td>
<td>3.4 (0.6)</td>
<td>3.7 (1.1)</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AP displacement (cm)</td>
<td>10.3 (2.4)</td>
<td>10.9 (2.0)</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>ML tilt</td>
<td>ML displacement (cm)</td>
<td>8.1 (1.7)</td>
<td>8.1 (1.6)</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AP displacement (cm)</td>
<td>5.2 (1.3)</td>
<td>5.3 (1.7)</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>

AP = anteroposterior; ML = mediolateral.
For example, Jadelis particular subgroups of elderly individuals cannot be excluded. Of pain itself from the other effects of the OA process. As such, it is difficult to differentiate the specific effects. [10, 11, 14] were all conducted in people with underlying knee pathology. As such, it is difficult to differentiate the specific effects. We are also currently evaluating the effects of knee pain on muscle performance. However, this has not been assessed in older people and results may differ in this age group. 

Balance measures of both a static and dynamic nature were incorporated to encompass the various domains of postural stability. Despite inducing knee pain of a moderate intensity, we found no effect of acute knee pain on any of the tested parameters of standing balance.

Our findings support those of Hassan et al. [15] who also investigated the effects of knee pain on balance in elderly people. In contrast to our study, these authors alleviated knee pain in patients with knee OA via bupivacaine injection. They found no improvement in static standing balance with short-term pain relief despite significant increases in quadriceps muscle strength. The authors surmised that certain dysfunctions caused by the OA process, such as impaired balance, may not be readily reversed by pain alleviation but require retraining over a prolonged time for improvement to occur. Similarly, it is likely that balance impairments do not readily result from an acute bout of knee pain but require prolonged nociceptive stimulation before balance performance deteriorates. Other studies which have demonstrated significant relationships between pain severity and balance deficits [10, 11, 14] were all conducted in people with underlying knee pathology. As such, it is difficult to differentiate the specific effects of pain itself from the other effects of the OA process.

Whilst we found no evidence of an effect of acute knee pain on balance in healthy people aged less than 60 yr, an effect in particular subgroups of elderly individuals cannot be excluded. For example, Jadelis et al. [14] found that higher pain scores were associated with poor balance in knee OA but only in the presence of quadriceps weakness. In those people with stronger muscles, pain was not related to balance performance. This suggests that the degree of integrity of each of the various physiological systems contributing to postural control will determine whether balance deficits become apparent in a particular individual. Under normal circumstances, the postural control system may be able to compensate for any adverse effects of pain if other physiological systems are intact. However, pain in combination with other abnormalities such as muscle weakness or impaired proprioception may produce measurable reductions in balance. Other studies have confirmed this hypothesis. In patients suffering from Parkinson’s disease, a condition associated with poor balance, standing balance was further reduced when they were asked to perform a simple motor task (thumb opposition to the fingers) [21]. The balance system, already compromised due to the pathological process of Parkinson’s disease, was unable to cope with the addition of a simple cognitive distraction task.

In our study, most balance measurements were bilateral lower limb tests with the exception of the step test. However, knee pain was only induced unilaterally, which may account for the non-significant changes in balance across experimental conditions. It is possible that a true decrement in balance performance was masked by the asymptomatic limb compensating for the painful limb. However, the step test is a unilateral balance test (requiring participants to balance on the painful limb while stepping the asymptomatic limb up and down onto a step) that should have elucidated balance deficits if this were the case.

Previous studies have demonstrated balance deficits approximating 30% in magnitude in patients with knee OA compared with healthy aged-matched controls [10, 11]. Using their data, we would have needed eight participants for the step test and 10 participants for the sway measures to have adequate power (>80%) to detect differences in balance equivalent to these other studies. In our study, reductions in balance with knee pain were all less than 9% from the control condition, except for one parameter where it was 34%. Our sample size was relatively small due to the invasive nature of the experimental procedure, which may help explain our non-significant effects. A post hoc power calculation based on our actual data demonstrated that we had 64% power to detect the largest mean difference in sway with knee pain (34%) noted in our study. However, the clinical relevance of the small changes with knee pain we found in all other balance parameters is questionable.

Furthermore, the mean effect of pain on balance was inconsistent for sway in the mediolateral direction. For example, pain was associated with a 7% reduction in mediolateral sway in the stable condition whilst other conditions demonstrated increased sway with knee pain. Greater consistency was evident with regards to anterior–posterior sway whereby knee pain resulted in increased sway across all platform conditions, albeit non-significantly. This may be due related to the principal (sagittal) range of motion to the knee and location of the knee pain.

Experimentally induced pain is transient in nature and does not necessarily replicate physiological chronic knee pain as experienced with conditions such as knee OA. We chose the infrapatellar fat pad as the site of nociceptive stimulation because it has been acknowledged as a highly pain sensitive structure around the knee [22] and identified on magnetic resonance imaging as a potential cause of knee pain in people with knee OA [23]. Furthermore we wished to avoid an intra-articular injection due to the ethical implications arising from the small but serious risk of joint infection. The source of pain in knee OA is unclear and may arise from a variety of structures including subchondral bone, ligaments, bursa and synovium [24]. Whether pain induced in other knee structures, particularly intra-articular structures, influences balance in a different manner to that induced in the fat pad is currently unknown. There is also the potential that the volume of fluid we injected to cause pain may itself affect balance. However, the amount we injected was extremely small, 0.20–0.25 ml, and is less than 9% from the control condition, except for one parameter ( > 80%) to detect differences in balance equivalent to these other participants for the sway measures to have adequate power.

Balance is a complex task, and our chosen balance measures incorporated components of muscle strength, endurance and joint proprioception. Whilst pain could have altered any or all of these components in our study, any effects were of insufficient magnitude to result in a measurable balance deficit. Using an identical experimental pain model we have shown no effect of knee pain on knee proprioception in younger healthy individuals [25].
In summary, this study found that acute experimentally induced knee pain of moderate intensity in healthy older individuals is insufficient to impair standing balance. Thus, strategies designed to reduce pain in treatment of knee pathology may not necessarily lead to improvements in balance. It is possible that muscle weakness or poor proprioception may be the major contributors to altered balance in this group and that muscle strengthening and/or proprioceptive retraining may be more appropriate treatments. Further research is required to determine the specific causes of balance impairments in people with knee pathologies such as OA. This will allow the identification of optimal treatment strategies for balance problems in the osteoarthritic population.

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References