Role of knee kinematics and kinetics on performance and disability in people with medial compartment knee osteoarthritis

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Abstract

Background. Although gait characteristics have been well documented in people with knee osteoarthritis, little is known about the relationships between gait characteristics and performance or disability. Our purpose was to examine the role of knee kinematics and kinetics on walking performance and disability in people with knee osteoarthritis. We also examined whether pain mediated the relationship between the knee adduction moment and performance or disability.

Methods. Three-dimensional gait analysis was conducted on 54 people with medial compartment knee osteoarthritis. Performance was quantified with the Six Minute Walk test and disability was self-reported on the Short Form-36. The pain subscale of the Western Ontario McMaster Universities Osteoarthritis Index and the functional self-efficacy subscale of the Arthritis Self-Efficacy scale were completed.

Findings. A step-wise linear regression demonstrated that the variance in Six Minute Walk test scores was explained by functional self-efficacy (50%) and the range of knee motion (8%). The variance in Short Form-36 was explained by pain (36%), the peak extension angle (19%) and the range of knee motion (4%). Pain was unrelated to the knee adduction moment so analyses of pain as a mediator of the adduction moment on either performance or disability were halted.

Interpretation. Kinematic output from the motor control system is useful in understanding some variance in current performance and disability in people with knee osteoarthritis. The knee adduction moment was unrelated to these variables and pain did not mediate between the knee adduction moment and performance or disability. Therefore this moment does not explain current clinical status in people with knee osteoarthritis based on the measures of performance and disability used in this study.

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1. Introduction

The prevalence of knee osteoarthritis (OA) makes this disease the single greatest cause of chronic disability in community-dwelling adults in the United States (Guccione et al., 1994). Although definitions vary, disability can be defined as an inability to fulfill a social role, such as work or family responsibilities (NIH, 1993). To quantify disability, researchers use self-report questionnaires that include items that reflect the impact of disease on social functioning. For example, Lingard and colleagues used the Short Form-36 (SF-36), which includes domains of emotional, physical and social functioning, as an outcome measure post-arthroplasty in a 2-year prospective study (Lingard et al., 2004). Although the SF-36 is frequently used as an outcome measure of disability, little research has examined the correlates of disability in people with knee OA. Our previous work showed that pain explained nearly 40% of the variance in SF-36 raw scores (Maly et al., 2006); but little is known about other factors that contribute to disability measures in people with knee OA.

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Because disability in people with knee OA has been linked to limitations in lower extremity mobility performance (Guccione et al., 1994), some research has attempted to uncover the determinants of physical performance. Walking is the activity most commonly reported as difficult by those with knee OA (Guccione et al., 1994). Self-efficacy, a person’s beliefs in their capabilities to organize and execute actions required to achieve a goal (Bandura, 1998), is an important determinant of walking performance in people with knee OA (Harrison, 2004; Sharma et al., 2003). In one study, self-efficacy explained 50% of the variance in the distance walked in 6 min in people with knee OA; while mechanical variables like strength and body weight contributed an additional 12% (Maly et al., 2005). It may be surprising that a psychosocial variable such as self-efficacy would contribute more to physical performance than mechanical variables. However, strength and obesity may not be the only or the most influential of mechanical variables affecting performance. Gait characteristics could explain variance in walking performance in knee OA. For example, altered knee loading during weight-bearing may result in pain due to intraosseous pressure, effusion and ischemia (O’Reilly and Doherty, 1998), which would interfere with walking performance. Thus, it is possible that gait mechanics would demonstrate a stronger relationship to walking performance than other mechanical variables previously studied in people with knee OA.

Gait analysis has proven useful in differentiating between people with and without knee OA. Compared to healthy adults, people with knee OA walk more slowly due to a shorter stride length or decreased cadence (Stauffer et al., 1977; Brinkman and Perry, 1985; Gok et al., 2002; Kaufman et al., 2001) and with decreased sagittal plane knee motion (Stauffer et al., 1977; Brinkman and Perry, 1985; Kaufman et al., 2001; Messier et al., 1992). Most studies show that the external knee adduction moment is greater in people with knee OA, even when compared to age, sex-matched controls (Gok et al., 2002). The adduction moment correlated with bone density distribution at the proximal tibia (Hurwitz et al., 1998) suggesting that it is a reasonable proxy for medial loading. The adduction moment also relates to disease severity and progression (Miyazaki et al., 2002; Wada et al., 2001; Sharma et al., 1998) and change in pain intensity with medication (Hurwitz et al., 2000). In the presence of pain, the knee adduction moment is lower during stair-climbing or walking (Schnitzer et al., 1993; Hurwitz et al., 2000; Shrader et al., 2004). It is possible that this moment will relate strongly to performance and disability, but these relationships are unclear. Also unclear is whether an elevated knee adduction moment directly results in pain. It is possible that pain mediates a relationship between elevated medial loading and performance or disability (Fig. 1). A mediator is a variable (e.g., pain) that represents a mechanism through which an independent variable (adduction moment) influences the dependent variable of interest (performance) (Baron and Kenny, 1986).

Other gait mechanics may also be important to walking performance, including external rotation (Gok et al., 2002), flexion (Kaufman et al., 2001) and extension moments (Hurwitz et al., 2000). These kinetic variables have not been studied extensively, yet these may be useful in understanding performance. For example, people with knee OA have a higher peak knee flexor moment, which is thought to improve joint stability during level walking (Schipplein and Andriacchi, 1991). Because our current knowledge about the role of various gait characteristics on walking performance in people with knee OA is limited, we aimed to explore a variety of kinematic and kinetic variables as potential determinants of performance.

The purpose of this study was to examine the role of three-dimensional knee angles and moments on walking performance and self-reported disability. Because self-efficacy is a known determinant of performance and knee pain is a known determinant of self-reported disability, we controlled for these variables. Second, we investigated whether pain mediated the relationship between the adduction moment and both walking performance and disability. We hypothesized that (1) controlling for self-efficacy, knee kinematics and kinetics will be significantly related to performance; (2) controlling for pain, knee kinematics and kinetics will be significantly related to disability and (3) pain will mediate a relationship between the knee adduction moment and disability.

2. Methods

2.1. Participants

Fifty-seven participants were involved. Data from three participants were excluded because radiographs taken during the study showed predominantly lateral knee OA. Intervention studies and theories of pathology suggest that lateral OA may involve different mechanics from that of medial (Ogata et al., 1997; Cerejo et al., 2002).

The remaining sample of 54 adults were over age 50 (mean = 68.3, SD = 8.7) with physician-diagnosed medial knee OA. The diagnosis was made by family physicians in all but in two cases where the diagnosis was made by an orthopaedic surgeon. Diagnosis was consistent with
the American College of Rheumatology (ACR) criteria, either based on radiographs or clinical signs and symptoms (Altman et al., 1986). Radiographs were taken at the beginning of the study to confirm the presence of medial OA. Participants were recruited by use of a free community newspaper that is circulated to over 55,000 homes.

Of the 54 participants, 32 were women and the left limb was studied in 29 cases. In cases of bilateral knee OA (n = 26) the more painful knee was tested. As a group, participants were highly educated (years of full-time formal education: mean = 14.9, SD = 4.3). No participant had undergone corrective surgery or had had an ipsilateral hip or ankle condition. All participants were screened for medical conditions that could be exacerbated by the protocol, such as unstable heart disease. Participants had an average of 2.5 comorbidities, defined as conditions that required treatment for more than 3 months by a physician. The most common comorbidities were hand OA, heart disease, low back pain and hypertension. All participants provided written informed consent before enrollment. Table 1 summarizes the descriptive data regarding the participants.

2.2. Dependent variables

2.2.1. Physical performance

The Six Minute Walk test (SMW) quantified walking performance. The SMW yields reliable (intraclass correlation coefficient = 0.96), valid data (Cahalin et al., 1996) and is an inexpensive clinical tool that records the distance that a participant covers at their own pace for 6 min while walking indoors. The SMW permits participants to use a mobility aid (e.g., cane) or pause. The SMW test was recorded indoors in a well-lit, 25 m tiled hallway. The score was the total distance traveled during 6 min. Participants were asked to “walk as quickly and safely as you can for 6 min.”

2.2.2. Disability

The SF-36 self-report questionnaire quantified disability, recognizing that this measure reflects part of but probably not all aspects of disability. The SF-36, a culmination of previously used scales in the medical outcomes study (Ware and Sherbourne, 1992), is a 36-item questionnaire that measures eight parameters: physical and social functioning, role limitations due to emotional or physical problems, mental health, bodily pain, vitality and general health perceptions. The reliability (median reliability coefficient 0.85 for all subscales) has been established (Ware and Sherbourne, 1992; McHorney et al., 1993, 1994; Brazier et al., 1992). The SF-36 has distinguished between elderly people with and without poor health, suggesting that the instrument yields valid data in this population (Lyons et al., 1994). Raw scores, out of 800, where a high score is positive (low disability), are presented.

2.3. Independent variables

2.3.1. Pain

The pain subscale (PAIN) of the Western Ontario McMaster Osteoarthritis Index (WOMAC) was chosen to assess pain because it asks about pain intensity during walking and stair-climbing. The WOMAC is a self-administered questionnaire, for patients with hip or knee OA, consisting of 24 questions categorized in subscales of pain, stiffness and physical function (Bellamy et al., 1988a). Using a visual analog format, items on the WOMAC scores can range between 0 and 100 mm, best to worst scores. The reliability and validity of the WOMAC has been well established, including the use of the subscales separately (Bellamy et al., 1988a,b).

2.3.2. Self-efficacy

The functional self-efficacy subscale (FSE) of the Arthritis Self-Efficacy scale was used to determine self-efficacy for physical tasks; that is, a person’s belief that he or she can perform a physical task like walking (Lorig et al., 1989). The FSE contains nine questions and uses a visual analog scale in which a higher score indicates greater self-efficacy, a positive result. A test–retest reliability coefficient (r) of 0.89 and a Cronbach’s alpha of 0.93 to test internal reliability were reported for use of the FSE alone (Lorig et al., 1989).

Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>Age (year)</td>
<td>68.3</td>
<td>8.7</td>
<td>50–87</td>
</tr>
<tr>
<td></td>
<td>Education (year)</td>
<td>14.9</td>
<td>4.3</td>
<td>8–30</td>
</tr>
<tr>
<td></td>
<td>Weight (kg)</td>
<td>82.2</td>
<td>15.0</td>
<td>52–127</td>
</tr>
<tr>
<td></td>
<td>Height (cm)</td>
<td>169.7</td>
<td>10.0</td>
<td>149.2–190.5</td>
</tr>
<tr>
<td></td>
<td>Chronic comorbidities (n)</td>
<td>2.5</td>
<td>1.3</td>
<td>0–6</td>
</tr>
<tr>
<td>Dependent measure</td>
<td>Six Minute Walk test (m)</td>
<td>440</td>
<td>123</td>
<td>146–642</td>
</tr>
<tr>
<td></td>
<td>Short Form-36</td>
<td>507</td>
<td>128</td>
<td>235–744</td>
</tr>
<tr>
<td>Independent measure</td>
<td>Functional self-efficacy subscale (%)</td>
<td>80.7</td>
<td>13.4</td>
<td>39.7–98.3</td>
</tr>
<tr>
<td></td>
<td>Pain‘ (/100)</td>
<td>30.3</td>
<td>18.6</td>
<td>3.2–89.2</td>
</tr>
</tbody>
</table>

a Comorbidities diagnosed by a physician and requiring ongoing treatment (>3 months) (excluding knee osteoarthritis).

b Scores range between 0 (poor) and 100 (excellent) on this subscale of the Arthritis Self-Efficacy scale.

c Pain subscale of the Western Ontario and McMaster Universities Osteoarthritis Index.

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2.3.3. Gait

Eighteen gait variables were measured. Three-dimensional knee angle and moment waveforms were calculated. From each, three variables were identified: positive and negative peaks and range between peaks. Gait data were collected using the gait analysis in three dimensions (GAIT) system, which has been validated for dynamic knee assessment (DeLuzio et al., 1993; Costigan et al., 1992). This system incorporates knee alignment and joint surface geometry data from standardized radiographs to more accurately transform the surface marker location into participant-specific joint centers. GAIT combines an Optotrak optoelectric system (Northern Digital, Canada), a force plate (Advanced Mechanical Technology, USA), precision radiographs and custom processing and analysis. The model incorporates the inertial characteristics of the foot in the shank. Infrared emitting diodes (IREDs) were placed over the greater trochanter, lateral femoral condyle, fibular head, lateral malleolus and distally on two projecting wands attached to the thigh and shank. We did not incorporate methods to minimize error due to skin motion, such as IRED clusters (Alexander and Andriacchi, 2001). Walking trials (force plate and motion detection) were sampled at 100 Hz. Vertical ground reaction force was used to indicate initial foot contact and center of pressure was used as the application point for the external ground reaction force.

Standardized radiographs were taken to calculate participant-specific correction vectors for surface IREDs. A correction vector was defined as a vector from the IRED location indicated by a lead bead, to joint center; this method has been detailed elsewhere (Kirkwood et al., 1999). Anthropometrics including body weight, height, limb circumferences and widths were measured. The conventions used for this study are illustrated in Fig. 2. Regression equations developed by Clauser et al. (1969) were used to identify segment mass and segment center of mass. The floating axis system developed by Grood and Suntay was used to calculate relative angles (Grood and Suntay, 1983). Net moments were calculated using a linked-segment model consistent with Winter (1990). External knee moments were determined from an inverse dynamics approach and were expressed per kilogram of body mass.

2.4. Protocol

Participants attended two visits, one week apart. In all but three cases, the second visit occurred within one week of the first. In the three cases where data were collected more than one week apart, the WOMAC was completed at both visits to confirm that status had not changed. During visit 1, after providing written informed consent, IRED locations were identified and marked for radiographs and gait. Standardized standing radiographs were taken by a trained radiology technician. Five gait trials were collected. The starting point of the walking trials was adjusted to ensure that the participants did not aim for the force plate. Trials where the force profiles appeared unreasonable or there were missing motion data (>2 consecutive points at 100 Hz) were excluded and repeated. The PAIN and SF-36 questionnaires were completed. During visit 2, the SMW and FSE were completed.

2.5. Statistical analysis

Descriptive statistics were calculated on the participant characteristics, dependent variables (SMW, SF-36) and self-report questionnaires (FSE, PAIN). For the knee angles and moments, the positive and negative peaks were identified in three dimensions and averaged across five trials. Also, maximum range values were averaged across five trials. Therefore, for each gait waveform three variables were identified: two peaks and a range.

2.5.1. Correlations

Pearson Correlation Coefficients were calculated. Bonferroni correction for 36 correlations at an alpha level of 0.05 in a two-tailed test requires a P-value < 0.001 for significance.

2.5.2. Regression

Multivariate analyses were used to investigate which factors explained performance. A two-block step-wise linear regression was performed using the SMW as a dependent measure. Block 1 included FSE, PAIN and block 2 included all gait variables significantly correlated with SMW. The same procedure was repeated using the SF-36 as the dependent variable. In the regressions, an F value of 0.05 or greater was necessary to be included and an F
value of 0.10 or less was necessary to be removed from the model. Tolerance values were examined for multicollinearity.

2.5.3. Mediation

We elaborated on the three criteria proposed by Baron and Kenny to identify whether pain mediated the relationship between the knee adduction moment with each of performance and disability (Fig. 1) (Baron and Kenny, 1986). First, a relationship, explored with a linear regression, must exist between pain and the knee adduction moment. Second, a relationship must exist between the SMW and knee adduction moment to ensure that joint loading relates to performance. Finally, a step-wise regression must show that controlling for the mediator (pain) reduces the effect of the independent variable (knee adduction moment) on the dependent (SMW). The procedure was repeated with the SF-36. All analyses were completed using SPSS v12 (SPSS Inc., Chicago).

3. Results

Descriptive statistics are presented in Table 1. Participants were overweight, with a body mass index of 28.6 kg/m². The 18 gait variables are presented in Table 2.

3.1. Correlations

Correlation coefficients \( r \) between the gait variables and the SMW ranged between 0.01 and 0.65. Significant relationships existed between the SMW and peak extension angle and range of flexion/extension angle. The significant correlations between SF-36 and gait variables involved the same kinematic variables (Table 3). Range of flexion/extension angle was related to the peak extension angle \( r = -0.58 \).

Table 2
Descriptive gait variables \((n = 54)\)

<table>
<thead>
<tr>
<th>Knee</th>
<th>Axis</th>
<th>Gait variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angles</td>
<td>X</td>
<td>Peak adduction angle (°)</td>
<td>9.4</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak abduction angle (°)</td>
<td>1.6</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (°)</td>
<td>7.8</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Peak flexion angle (°)</td>
<td>64.3</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak extension angle (°)</td>
<td>8.8</td>
<td>7.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (°)</td>
<td>55.5</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>Peak internal rotation angle (°)</td>
<td>3.8</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak external rotation angle (°)</td>
<td>-8.1</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (°)</td>
<td>11.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Moments</td>
<td>X</td>
<td>Peak adduction moment (N m/kg)</td>
<td>0.46</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak abduction moment (N m/kg)</td>
<td>-0.06</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (N m/kg)</td>
<td>0.52</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>Peak flexion moment (N m/kg)</td>
<td>0.27</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak extension moment (N m/kg)</td>
<td>-0.27</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (N m/kg)</td>
<td>0.54</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>Peak internal rotation moment (N m/kg)</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak external rotation moment (N m/kg)</td>
<td>-0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range (N m/kg)</td>
<td>0.14</td>
<td>0.05</td>
</tr>
</tbody>
</table>

SMW = Six Minute Walk test, SF-36 = Short Form-36 questionnaire.

* Correlation is significant at a P-value of <0.001 (two tailed, Bonferroni correction for 48 comparisons).

3.2. Role of gait variables on performance and disability

The step-wise linear regression models that explain the variance in the SMW and SF-36 are shown in Table 4. In both, tolerance statistics were over 0.85 and the indepen-
dent variables were entered in two blocks: block 1 included FSE and PAIN, block 2 included range of flexion/extension angle and peak extension angle.

For the model of physical performance, the FSE (50%) and the range of flexion/extension angle (8%) explained the variance in SMW scores. For the model of self-reported disability, pain explained 36% of the variance in the SF-36. The peak extension angle added another 19% and the range of peak flexion/extension explained another 4% of the SF-36.

The regression analyses were repeated forcing the knee adduction moment in the second block of independent variables. No difference in either regression model resulted. We also repeated the step-wise linear regression analyses excluding FSE and PAIN to identify if gait mechanics would show better relationships with walking performance and disability. The resultant model for the SMW included the range of flexion/extension angle and the peak extension angle to explain 41% of the variance. Because this model explained 17% less variance than the original, it was discarded. The model calculated for the SF-36 also included these variables, in the opposite order, to explain 48% of the score variance. This model was also discarded because it explained 11% less than the original model.

3.3. Pain as a mediator

The linear regression examining whether the knee adduction moment related to pain was not significant (unstandardized coefficient = 32.9, Adjusted $R^2 = 0.02$, $P < 0.668$). The analyses of mediation were not completed because this first criterion was not met.

4. Discussion

The purpose of this study was to explore the role of three-dimensional knee angles and moments on walking performance and self-reported disability. We theorized that the knee adduction moment, a proxy for medial loading, would create pain during weight-bearing activities, thereby limiting walking performance and contributing to disability. Self-efficacy and the dynamic range of knee flexion/extension motion were related to walking performance. Pain, the peak knee extension angle and range of motion were statistically related to disability. Therefore, knee angles helped to explain current levels of performance and self-reported disability in people with mild-to-moderate knee OA. The knee adduction moment did not relate to current levels of performance or self-reported disability and therefore did not explain current clinical status in this population.

Our first hypothesis that controlling for self-efficacy, knee kinematic and kinetic variables would significantly relate to performance was supported. As we anticipated (Harrison, 2004; Sharma et al., 2003), the FSE was strongly related to walking scores. In this study we found that a person with an FSE score higher by 10%, indicating a higher level of confidence for physical tasks, walked an extra 52 m compared to his/her peers. The minimal detectable change in the SMW in this population is 61 m (Kennedy et al., 2005). An education-based intervention improved self-efficacy by 16% at a four year follow-up (Lorig et al., 1993) suggesting that improving self-efficacy alone is possible and could result in a clinically significant improvement in walking performance. Our findings also show that over and above the effects of FSE, the sagittal knee range of motion was a determinant of walking performance. Limitations in the dynamic range of sagittal plane knee motion in people with knee OA are well documented (Stauffer et al., 1977; Brinkman and Perry, 1985; Kaufman et al., 2001; Messier et al., 1992) and knee range of motion is related to radiographic disease severity (Ersoz and Ergun, 2003). Our findings suggest a person with $10^\circ$ greater total range of motion during gait walked 38 m further on the SMW, a substantial increase from a clinical perspective. For some people, improving dynamic range of motion by $10^\circ$ is possible through exercise but the clinical relevance of this improvement on walking performance is questionable. Interestingly, six month outcomes following arthroplasty demonstrate that total knee range of motion is decreased by approximately $20^\circ$ (Beaupre et al., 2001) suggesting that walking performance may be significantly impaired. Further research is necessary to confirm this effect of range of motion on walking performance.

Our hypothesis that controlling for pain, knee kinematic and kinetic variables would significantly relate to self-reported disability was supported, though the clinical importance warrants further discussion. The data show that pain explained 36% of the variance in the SF-36 such that the greater a person’s self-reported pain intensity, the
greater their self-reported level of disability. The clinical significance of this effect may be small however, because a person reporting 10% less pain would only experience an increase of 5 out of 800 points on the SF-36. The peak knee extension angle, which occurs at either loading response or terminal swing in the gait cycle, contributed to the regression model over and above pain, indicating a statistically significant role of output from the motor control system on disability. A reduction in full extension at terminal swing shortens the stride thereby limiting walking ability necessary for socially relevant activities. Those unable to achieve near full extension during loading response risk loading the extensors eccentrically to a greater extent. Improving knee extension by 10° would result in an increase in SF-36 raw score of 64 points. Because the mean peak extension angle in this study was 8.8° these finding suggest that clinicians could aim for full knee extension but this goal may not be practical in all cases. The third variable explaining disability was the sagittal knee range of motion. Similarly, the clinical significance for this finding is unclear. An increase in total range of knee motion by 10° would only increase SF-36 raw scores by 30 out of 800 points. Although gait mechanics are related to both performance and self-reported disability, the role of gait kinematics on disability appear more tenuous. This finding is not surprising given the complex nature of disability, which is influenced by many factors ranging from mechanical to societal (NIH, 1993). This conclusion is consistent with our finding that performance and self-report have different determinants (Maly et al., 2006).

Knee kinetics were not significantly related to either performance or self-reported disability suggesting that kinetics have limited value to contribute to the understanding of clinical outcomes, at least in a cross-sectional study of this nature. The knee adduction moment has particular significance in knee OA (Andriacchi et al., 2004). Forcing the adduction moment into the regression models did not change the result in our models incorporating this variable. However, our sample, recruited from the community, had relatively mild knee OA suggesting that the mean peak knee adduction moment would be low compared to a more severe population (Mundermann et al., 2005). Our findings do not discount the utility of the knee adduction moment in differentiating people with knee OA from others nor the possibility that this variable may be useful in tracking progression over time. Furthermore, we do not suggest that kinetics in general are unimportant to performance or disability because joint powers and energies should be strongly related to walking performance. For example, other researchers have demonstrated the utility of a power and energy approach to understanding compensatory gait mechanics in similar populations (McGibbon and Krebs, 2002).

Our third hypothesis suggested that pain intensity would mediate the relationship between medial loading and each of performance and disability. Our findings did not satisfy the criteria proposed by Baron and Kenny (1986): pain and the adduction moment were unrelated. Several factors may explain why these variables were unrelated in this cross-sectional study. First, the WOMAC pain subscale assesses “recent” pain which may not be the same as the pain that occurred during gait testing. For example, participants could have been experiencing a relatively “good” day during testing, leading to a poor correlation between pain reported on the WOMAC and the knee adduction moment recorded in the laboratory. Second, pain may result in complex compensatory strategies that complicate any relationship between pain and the adduction moment. For example, a prospective study demonstrated that after administering an analgesic, an increased adduction moment was observed (Schnitzer et al., 1993). Although these findings suggest that pain mitigated the knee adduction moment, there was no statistically significant correlation between the adduction moment and change in pain (Schnitzer et al., 1993).

Some limitations must be considered. Our gait protocol did not incorporate methods of controlling for skin marker motion, for example by using marker clusters but these effects were likely to be negligible given the purpose of this study. Some participants had bilateral disease which may have influenced the gait characteristics observed. In terms of generalizability, this sample appeared to have milder symptoms of OA than those involved in many studies, likely because we recruited from the community rather than surgical waiting lists. For example, these participants had relatively low levels of pain and the self-efficacy scores were considerably higher than those obtained in other studies.

Future research could be directed toward examining the effect of interventions to improve self-efficacy, pain and dynamic range of motion on performance and disability in people with knee OA. The construct of self-efficacy requires further study to more precisely model its role in performance in knee OA. It is also possible that we would have different results with a more severe or variable study sample. Finally continued research is necessary to develop more sophisticated models that provide insight into the meaning of performance and disability in people with knee OA.

5. Conclusions

This study examined the clinical significance of gait analysis in people with knee OA by exploring the relationships between knee angles and moments, pain, self-efficacy, performance and disability. Our findings demonstrated that kinematic output from the motor control system is useful in understanding some variance in current levels of performance and disability in people with knee OA, over and above self-efficacy and pain respectively. Despite the theoretical importance of the knee adduction moment, it was unrelated to performance and disability. Our proposed model that pain mediated between the knee adduction...
moment and performance or disability was not supported. Therefore, the adduction moment does not explain current clinical status of performance and disability in people with mild-to-moderate knee OA.

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References


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