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Weight-Bearing Asymmetry in Relation to Measures of Impairment and Functional Mobility for People With Knee Osteoarthritis

Cory L. Christiansen, PT, PhD and Jennifer E. Stevens-Lapsley, PT, PhD

Department of Physical Medicine and Rehabilitation, University of Colorado Denver, Aurora, CO (Christiansen, Stevens-Lapsley)

Abstract

Objective—To compare weight-bearing asymmetry (WBA) for people with unilateral knee osteoarthritis (OA) to healthy adults of similar age. In addition, associations between WBA and clinical measures of knee impairment and functional mobility were evaluated.

Design—Cross-sectional design with age-matched control (CTL) group.

Setting—Clinical research laboratory.

Participants—People with end-stage unilateral knee OA (n=50) (OA group) and healthy people (n=17) (CTL group) were enrolled in the study.

Interventions—Not applicable.

Main Outcome Measures—WBA during a Five Times Sit-to-Stand Test (FTSST) based on average vertical ground reaction force under each foot, self-reported knee pain assessed using a Numerical Pain Rating Scale, knee extensor strength asymmetry based on peak isometric knee extension torque, knee motion asymmetry based on maximum passive knee extension and flexion angles, FTSST time, Six-Minute Walk Test distance, and Stair Climbing Test time.

Results—The OA group demonstrated greater WBA than that of the CTL group during transitions between sitting and standing as measured by an absolute symmetry index ($P = 0.015$). No correlation was found between WBA and knee motion asymmetry, but comparisons of WBA to all the other outcome variables indicated fair relationships (ranging from $r = 0.29 - 0.44$).

Conclusions—Weight-bearing asymmetry during transitions between sitting and standing can serve as a clinically relevant measure related to both knee impairment and functional mobility for people with unilateral knee OA.

Keywords

Biomechanics; Knee; Osteoarthritis; Rehabilitation

Alterations in functional movement patterns have been noted in patients with knee osteoarthritis (OA), characterized by compensations to reduce loading of the affected limb.¹⁻⁴ The weight-bearing asymmetry (WBA) created by these altered movement patterns has been documented during performance of common daily tasks such as walking³ and stair

climbing.⁴ For people with unilateral knee OA, WBA can persist even after pain is reduced with intervention such as total knee arthroplasty (TKA).^{1, 5-7}

Functional mobility may be directly influenced by WBA. For example, Asay and colleagues⁴ examined symmetry of weight-bearing measures during stair climbing activity for people with knee OA. They found that people with unilateral knee symptoms adapted asymmetric movement patterns resulting in reduced net knee extension demand moments on the affected side. Additionally, asymmetric movement patterns were more pronounced as OA severity increased and were related to poorer reports of function.⁴

Transitions between sitting and standing are fundamental to daily activity and identified as a key functional problem for people with knee impairment.^{5, 7} There is indication that WBA may be problematic during transitions between sitting and standing for people with unilateral knee OA¹, however no direct WBA comparison has been made between people with knee OA and healthy individuals. Based on these considerations, transitions between sitting and standing were chosen as the functional activity to examine when measuring WBA in the current investigation.

It has been suggested that WBA is a response to unilateral knee pain in patients with OA.³ Indeed, pain is a problem and has been correlated with physical activity performance for people with knee OA.⁸ However, findings of asymmetric movement patterns in the absence of pain indicate that other factors may perpetuate WBA when pain is not a primary problem.⁴ Factors suggested to contribute to WBA include habitual movement pattern,⁷ impaired quadriceps femoris function,^{4, 6} and impaired knee joint motion.⁹ Currently, no study has examined associations between these factors and WBA. Identification of associations between WBA and impairments related to progression of knee OA is necessary in order to develop effective interventions that minimize symptoms and maximize function.

There were two purposes of this study. The first purpose was to compare WBA for people with end-stage unilateral knee OA to healthy adults of similar age. The second purpose was to identify associations between WBA in people with unilateral knee OA and clinical measures of knee impairment and functional mobility. The hypotheses were: 1) Patients with OA would demonstrate WBA during transitions between sitting and standing that was greater than typical WBA measured in healthy individuals and 2) WBA would be positively correlated with pain, knee extensor strength asymmetry, and knee motion asymmetry and negatively correlated with functional mobility.

Methods

Participants

Participants for the OA group were recruited from the patients of three orthopedic surgeons at the University of Colorado Hospital prior to TKA from October 2008 to December 2009. Only patients with unilateral knee OA were included, defined by patients reporting no more than half the level pain on their non-affected knee compared with their affected knee (based on a numerical pain rating scale (NPRS) of 0-10). Volunteers were excluded if they were not within the age range of 50 to 85 years, had uncontrolled hypertension, uncontrolled diabetes, body mass index > 35 kg/m², neurologic impairment, had non-affected knee pain greater than 4/10, or other lower-extremity orthopedic problems.

Recruitment for the CTL group was made by verbal and written announcement in the community from December 2008 to March 2009. Exclusion criteria for CTL group volunteers were identical to the OA group with additional criteria that CTL volunteers be excluded if they did not exercise a minimum of 3 days per week (30 minutes/day), had knee pain greater than

2/10 on an intermittent basis (based on a NPRS of 0-10), or had any knee pain with regular daily activity.

The Colorado Multiple Institutional Review Board approved the study and written informed consent was obtained from all participants.

Weight-Bearing Asymmetry (WBA)

Measurement of WBA was achieved with vertical ground reaction force (vGRF) data obtained from two force platforms^a located under each foot of the participant during a timed Five Times Sit-to-Stand Test (FTSST)¹⁰ (see Functional Mobility Measures section for FTSST details). The force platform offsets were reset (i.e., zeroed) prior to each testing session. Average vGRF was calculated for each limb from start to end time of the FTSST. The vGRF values were normalized by dividing vGRF by body weight. To describe WBA in the OA group, the ratio of average vGRF value for the affected limb was divided by average vGRF for the non-affected limb to create a loading symmetry ratio (Equation 1).

$$\text{Loading Symmetry Ratio} = \text{vGRF}_A / \text{vGRF}_{NA}$$

vGRF_A = average vertical ground reaction force under affected limb
 vGRF_{NA} = average vertical ground reaction force under non – affected limb

(Equation 1)

Using a ratio equation to describe asymmetry is recommended when there is an identifiable affected side, as the results of this calculation are relatively easy to interpret.¹¹ For example, a ratio of 0.8 would indicate that the affected limb is loaded at a level 80% of the non-affected limb. For our study, the symmetry ratio allowed direct interpretation of WBA in terms of the relation between affected and non-affected limbs. However, for healthy individuals with no identifiable “affected” limb it would be arbitrary to select a limb for a ratio calculation. For example, a left over right limb ratio of 1.05, would be equivalent to a right over left limb ratio of 0.95. For this reason, we chose to use an absolute symmetry index (ASI)¹², which indicates absolute differences between limbs without regard to affected or non-affected limbs, to compare the OA and CTL groups (Equation 2). An ASI value of zero would indicate perfect symmetry.

$$\text{ASI} = 2 * |(\text{vGRF}_L - \text{vGRF}_R) / (\text{vGRF}_L + \text{vGRF}_R)| * 100\%$$

vGRF_L = average vertical ground reaction force under left limb
 vGRF_R = average vertical ground reaction force under right limb

(Equation 2)

Knee Impairment Measures

Three knee impairment measures were used in this study: self-reported knee pain, knee extensor strength asymmetry, and knee motion asymmetry. The first measure, self-reported knee pain, was assessed using a Numerical Pain Rating Scale (NPRS) from 0-10, with 0 representing no pain and 10 being the worst possible pain. Participants reported the level of pain for their affected knee immediately following the FTSST.

The second impairment measure was knee extensor strength asymmetry. Maximum isometric knee extension torque was measured using an electromechanical dynamometer^b. Participants were seated with their hips flexed at 85° and knees flexed at 60°. During this test, participants

^aSupplier: PASCO scientific, 10101 Foothills Blvd, Roseville, CA 95747.

^bSupplier: CSMi, 101 Tosca Dr, Stoughton, MA 02072.

were instructed to provide their maximum knee extension effort and peak torque values were recorded. Two warm-up trials were performed prior to performance of 3 test trials, in which the torque values were recorded. For each limb, the peak torque value of the 3 test trials was used. Data from the electromechanical dynamometer were sampled at a frequency of 2000 Hz. During the measured trials, a monitor displayed a visual torque target that was at a slightly greater value than produced during the practice trials. Verbal encouragement was also used to elicit maximal effort. Knee extensor strength asymmetry was described using a symmetry ratio and ASI created from the peak torque values of each limb for the OA group and ASI for the control group.

The final knee impairment measured was joint motion, measured as maximal passive knee extension and flexion angles. Joint motion was measured using a universal manual goniometer with the participant positioned in supine. In this position, the proximal arm of the goniometer was aligned along the long axis of the thigh and the distal arm aligned along the long axis of the leg. To measure maximal passive knee extension, the participant's heel was placed on a block and pressure was applied by a tester on the distal thigh until a firm end feel was felt in knee extension. Maximal passive knee flexion was recorded as pressure was applied to the distal leg into knee flexion by a tester. Inter- and intra-tester reliability for goniometric measures of knee motion are high to very high (ICC range 0.70-0.99).^{13, 14} Maximal passive knee extension and flexion angles were used to calculate knee motion symmetry ratios and ASI values for the OA group and ASI values for the control group.

Functional Mobility Measures

Three standardized clinical measures were used to assess functional mobility: the Five Times Sit-to-Stand Test (FTSST), the Six-Minute Walk Test (6MWT), and the Stair Climb Test (SCT). The first measure, FTSST, was performed by each participant to quantify performance of transitions between sitting and standing.¹⁰ At the start of this test, participants were seated in a chair of standardized seat height (46 cm) with their feet placed on the center of each force platform in a participant-selected degree of comfortable knee flexion. The time (measured with a hand-held stop watch) taken to transfer 5 times between the sitting and standing positions as quickly as possible was recorded. The start and end point of the test was the participant seated with their back touching the backrest of the chair. Participants were given opportunity to practice the movement prior to testing and were instructed to perform the task as naturally as possible. Two trials were recorded and the fastest successful trial was used for analysis. Participants were encouraged to not use their hands during the test, neither on the chair arm rests nor the lower extremities. However, for participants who could not perform the movement without use of hands, armrest use was allowed and documented and the fastest time of the two trials was used for analysis.

The second functional mobility measure was the 6MWT, assessing gait function on a level surface. The 6MWT was originally developed as a measure of endurance for people with cardiovascular impairment.¹⁵ However, it is also a valid and reliable test for clinical measurement of gait function in a variety of populations, including individuals with knee OA.¹⁶⁻¹⁸ Participants walked as far as possible during a 6 minute time frame. They were instructed to stop and rest if needed during the 6 minutes. The 6MWT was performed in a 30.5 m (100 ft) corridor.

The third functional measure, the SCT, assessed the time required to ascend and descend one flight of stairs (12 steps, 17.1 cm step height). Timing was performed with a hand-held stop watch and began when subjects lifted their foot for the first step and ended when both feet returned to the landing at the base of the stairs. The SCT has been shown to be a reliable and valid measure of the high level function required to perform stair ambulation for people with

mobility limitations, including those with knee OA.^{19, 20} The shortest time required by each participant, out of two trials, was used.

Statistical Analysis

A sample size estimate for determining differences in WBA between the control (CTL) group and OA group was calculated on the basis of means and SD values available for the first 10 participants in the OA and CTL groups for the ASI. We determined the sample size for the OA group to be 50 based on the known number of 17 participants in the CTL group, a power level of 0.90, α level of 0.05, and a two-tailed t -test of difference between the group means.

Comparison of demographics and anthropometrics between the OA and CTL groups were assessed using independent t tests (for continuously scored variables) and a Fisher Exact Test (for sex distribution). An independent t test was also used to identify differences in WBA between the participants in the OA and CTL groups using the ASI. Knee extensor strength asymmetry and knee motion asymmetry were presented using the ASI for the OA and CTL groups, for visual comparison. Pearson product correlation coefficients were used to measure the bivariate relations between WBA and all other outcome measures. Unless otherwise specified, group values are reported as means (SD). The level of significance for the t test comparison of ASI between groups was set at $p < 0.05$. Confidence intervals were calculated for the interpretation of the Pearson's product correlation coefficients.

Results

Group Comparison

Descriptive data for the OA and CTL groups are included in Table 1. The participants ranged in age from 51 to 85 years in the OA group and 58 to 81 years in the CTL group. Statistical comparison of sex, age, body mass, and body height revealed no significant differences between groups. Also included in Table 1 are the WBA, functional mobility measures, and knee impairment measures for both groups.

Weight-Bearing Asymmetry (WBA)

There was a significant difference (p value = 0.015) noted between the two groups in WBA during the FTSST (Table 1), with the OA group having ASI values indicating greater asymmetry than the CTL group. Figure 1 presents vGRF traces during the FTSST for a typical participant in the OA group. The loading symmetry ratio for the OA group was 0.87 (0.15), indicating a mean loading of the affected limb at 87% of the non-affected limb. Forty-two of the 50 participants (84%) in the OA group loaded less weight on the affected limb compared to the non-affected limb; 8 participants did not demonstrate affected limb unloading. Eighteen of the 50 participants in the OA group were unable to perform the FTSST without assistance of their upper extremities, and all but one of these 18 participants (94%) had lower average v-GRF values on the affected side. The average loading symmetry ratio for participants using their upper extremities for assistance was 0.77 (0.13) compared to 0.93 (0.14) for people not using their upper extremities.

Correlations of WBA with Outcome Measures

No correlation was found between symmetry ratios of maximum knee angle (extension or flexion) and WBA. Correlations of WBA with all other measures were fair²¹ (ranging from 0.29 to 0.44) and showed WBA to be positively associated with pain and knee extensor strength asymmetry and negatively associated with functional mobility. These associations are illustrated in the negative correlations of vGRF symmetry ratio (note: a low value of symmetry ratio indicates a high level of asymmetry) with knee pain, FTSST time, and SCT time, while

positive correlations were identified for vGRF symmetry ratio with knee extensor strength symmetry ratio and 6MWT distance (Table 2).

Discussion

People with end-stage unilateral knee OA demonstrate greater WBA during transitions between sitting and standing than healthy adults of similar age. The observed WBA for the OA group is positively correlated to the impairments of pain and strength, but not knee motion. Additionally, there is a negative correlation between WBA and functional mobility during tasks requiring lower limb loading.

Asymmetry has been examined during functional tasks for people with OA.^{1, 3-5} The functional task of transitioning from sitting to standing is fundamental to performance of basic daily activities and is a valuable performance-based outcome measure for people with impaired knee function.^{7, 22} Boonstra and colleagues¹ have specifically looked at WBA during the sit-to-stand movement for people with knee OA, prior to and following unilateral TKA. While they did not statistically compare measures of WBA at the pre-surgical time point to a control group, graphical data presented in their paper indicate a trend toward differences between healthy individuals and individuals with OA in WBA. Our study verifies this trend, finding that a low level of WBA (CTL group ASI = 8.3 (7.8)) may be expected during transitions between sitting and standing for healthy individuals, although less than the WBA seen in people with unilateral knee OA (OA group ASI = 31.8 (23.2)).

The difference in WBA between the OA and CTL groups, as well as the larger variability in ASI for the OA group compared to the CTL group, indicate unique mechanisms of WBA for people with unilateral knee OA compared to healthy individuals. Several mechanisms related to knee OA have been proposed to cause WBA, including pain,³ habitual movement pattern,⁷ impaired quadriceps femoris function,^{4, 6} and impaired knee joint motion.⁹ While pain appears to be an intuitive explanation for WBA, there is some evidence that excessive movement asymmetry persists in the absence of pain symptoms.^{4, 6} For example, Asay and colleagues⁴ demonstrated differences in movement symmetry during stair climbing comparing groups of individuals with similar ratings of OA-related knee pain.

The participants in our study demonstrated associations between WBA and impairments of knee pain and quadriceps strength. However, symmetry of knee motion was not related to WBA. Harato and colleagues⁹ examined WBA in relation to knee motion for people after TKA for end-stage OA and found individuals who had less weight-bearing on their surgical limb compared to non-surgical limb tended to have less knee extension in the surgical limb during standing. Due to differences in measurement methods and the fact that participants in our study had not undergone TKA, our data cannot be directly compared to that of Harato and colleagues. However, it is possible that knee motion, particularly knee extension, may play a greater role in determining WBA after TKA than prior for people with unilateral OA.

It is reasonable to consider the potential symptomatic and functional consequences of WBA in people with unilateral knee OA. While WBA may provide individuals with a mechanism to decrease progression of OA in the affected knee, there is the potential of asymmetrical loading creating future problems. It has been suggested that WBA may lead to increased incidence of OA in the contralateral knee and/or hip. In support of this idea, Shakoor and colleagues²³ found the most common joint to be replaced following unilateral TKA, for people with knee OA, was the contralateral knee. In a subsequent study, Shakoor and colleagues²⁴ identified that WBA due to advanced unilateral hip OA is characterized by greater loading of the contralateral knee. Their suggestion was that loading asymmetry may promote the development of contralateral knee OA. Future study is needed to determine if the WBA we have identified in people with

knee OA prior to TKA may justify intervention, such as assistive device use or altered movement strategies, to decrease OA progression in the contralateral limb.

The associations between functional mobility and WBA are also clinically relevant. The sit-to-stand movement, 6MWT, and SCT are all valid tasks to measure physical mobility for people with knee OA.^{1, 16, 19} By identifying a negative relation between these measures of functional mobility and WBA, we have provided further support that correction of WBA should be considered as a potential target for intervention. Future study is warranted to determine if compensations to reduce WBA will promote function as well as limiting other detrimental consequences, such as contralateral joint problems.

Study Limitations

Causation for either the mechanisms related to WBA or the influence of WBA on function cannot be determined with correlations in a cross-sectional study. Due to potential confounding associations of pain, habitual movement patterns, impaired quadriceps femoris function, and impaired knee joint motion, it is important to separate these potential mechanisms for WBA before identifying which should be targets of clinical intervention. Future longitudinal studies designed to identify factors specific to knee OA are needed to further understand the mechanisms behind this functional problem and how it influences mobility. Additionally, our participants do not reflect the greater population of all individuals with knee OA. Participants in this study were all at the end-stage of unilateral knee OA, just prior to TKA surgery. A larger group of individuals across levels of OA severity is needed to examine WBA in relation to disease progression.

In order to promote a normal movement pattern between sitting and standing, participants were allowed to use their hands on the arm-rests if needed. However, it is possible that the 18 participants in this study who could not perform the FTSST without upper extremity support were compensating for the loading demands on the affected limb and that true WBA values were attenuated. Future investigation should examine if there is a maximum level of WBA that is achievable before upper extremity use is required.

Conclusions

People with end-stage unilateral knee OA demonstrate asymmetric loading of their lower limbs during transitions between sitting and standing. Additionally, greater amounts of WBA are correlated with greater knee pain, greater strength impairment, and poorer functional mobility. These results indicate the importance of considering both the cause and effects of chronic WBA when attempting to improve the health and function of people with knee OA.

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References

1. Boonstra MC, Schwering PJ, De Waal Malefijt MC, Verdonchot N. Sit-to-stand movement as a performance-based measure for patients with total knee arthroplasty. *Phys Ther* 2010;90(2):149–56. [PubMed: 20007664]

2. Rudolph KS, Schmitt LC, Lewek MD. Age-related changes in strength, joint laxity, and walking patterns: are they related to knee osteoarthritis? *Phys Ther* 2007;87(11):1422–32. [PubMed: 17785376]
3. Hurwitz DE, Ryals AR, Block JA, Sharma L, Schnitzer TJ, Andriacchi TP. Knee pain and joint loading in subjects with osteoarthritis of the knee. *J Orthop Res* 2000;18(4):572–9. [PubMed: 11052493]
4. Asay JL, Mundermann A, Andriacchi TP. Adaptive patterns of movement during stair climbing in patients with knee osteoarthritis. *J Orthop Res*. 2008
5. Su FC, Lai KA, Hong WH. Rising from chair after total knee arthroplasty. *Clin Biomech (Bristol, Avon)* 1998;13(3):176–81.
6. Mizner RL, Snyder-Mackler L. Altered loading during walking and sit-to-stand is affected by quadriceps weakness after total knee arthroplasty. *J Orthop Res* 2005;23(5):1083–90. [PubMed: 16140191]
7. Boonstra MC, De Waal Malefijt MC, Verdonchot N. How to quantify knee function after total knee arthroplasty? *Knee* 2008;15(5):390–5. [PubMed: 18620863]
8. Nebel MB, Sims EL, Keefe FJ, Kraus VB, Guilak F, Caldwell DS, et al. The relationship of self-reported pain and functional impairment to gait mechanics in overweight and obese persons with knee osteoarthritis. *Arch Phys Med Rehabil* 2009;90(11):1874–9. [PubMed: 19887211]
9. Harato K, Nagura T, Matsumoto H, Otani T, Toyama Y, Suda Y. Extension Limitation in Standing Affects Weight-Bearing Asymmetry After Unilateral Total Knee Arthroplasty. *J Arthroplasty*. 2009
10. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. *Phys Ther* 2005;85(10):1034–45. [PubMed: 16180952]
11. Patterson KK, Gage WH, Brooks D, Black SE, McIlroy WE. Evaluation of gait symmetry after stroke: a comparison of current methods and recommendations for standardization. *Gait Posture* 2010;31(2):241–6. [PubMed: 19932621]
12. Herzog W, Nigg BM, Read LJ, Olsson E. Asymmetries in ground reaction force patterns in normal human gait. *Med Sci Sports Exerc* 1989;21(1):110–4. [PubMed: 2927295]
13. Watkins MA, Riddle DL, Lamb RL, Personius WJ. Reliability of goniometric measurements and visual estimates of knee range of motion obtained in a clinical setting. *Phys Ther* 1991;71(2):90–6. discussion 6-7. [PubMed: 1989012]
14. Jakobsen TL, Christensen M, Christensen SS, Olsen M, Bandholm T. Reliability of knee joint range of motion and circumference measurements after total knee arthroplasty: does tester experience matter. *Physiother Res Int*. 2009
15. Guyatt GH, Sullivan MJ, Thompson PJ, Fallen EL, Pugsley SO, Taylor DW, et al. The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Can Med Assoc J* 1985;132(8):919–23. [PubMed: 3978515]
16. Parent E, Moffet H. Preoperative predictors of locomotor ability two months after total knee arthroplasty for severe osteoarthritis. *Arthritis Rheum* 2003;49(1):36–50. [PubMed: 12579592]
17. Parent E, Moffet H. Comparative responsiveness of locomotor tests and questionnaires used to follow early recovery after total knee arthroplasty. *Arch Phys Med Rehabil* 2002;83(1):70–80. [PubMed: 11782835]
18. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. *Phys Ther* 2002;82(2):128–37. [PubMed: 11856064]
19. Lin YC, Davey RC, Cochrane T. Tests for physical function of the elderly with knee and hip osteoarthritis. *Scand J Med Sci Sports* 2001;11(5):280–6. [PubMed: 11696212]
20. LeBrasseur NK, Bhasin S, Miciek R, Storer TW. Tests of muscle strength and physical function: reliability and discrimination of performance in younger and older men and older men with mobility limitations. *J Am Geriatr Soc* 2008;56(11):2118–23. [PubMed: 18811607]
21. Portney, GP.; Watkins, MA. Foundations of clinical research applications to practice. Upper Saddle River, NJ: Pearson Education; 2009.
22. Boonstra MC, Jenniskens AT, Barink M, van Uden CJ, Kooloos JG, Verdonchot N, et al. Functional evaluation of the TKA patient using the coordination and variability of rising. *J Electromyogr Kinesiol* 2007;17(1):49–56. [PubMed: 16455268]

23. Shakoor N, Block JA, Shott S, Case JP. Nonrandom evolution of end-stage osteoarthritis of the lower limbs. *Arthritis Rheum* 2002;46(12):3185–9. [PubMed: 12483722]
24. Shakoor N, Hurwitz DE, Block JA, Shott S, Case JP. Asymmetric knee loading in advanced unilateral hip osteoarthritis. *Arthritis Rheum* 2003;48(6):1556–61. [PubMed: 12794823]

List of Abbreviations

6MWT	Six Minute Walk Test
ASI	Absolute Symmetry Index
CTL	Control
FTSST	Five Times Sit to Stand Test
ICC	Intraclass Correlation Coefficient
NPRS	Numerical Pain Rating Scale
OA	Osteoarthritis
SCT	Stair Climb Test
TKA	Total Knee Arthroplasty
WBA	Weight-Bearing Asymmetry
vGRF	Vertical Ground Reaction Force

Figure 1. Vertical ground reaction force during the Five Times Sit to Stand Test for affected and non-affected limb of a representative participant in the OA group (force normalized to body weight). Horizontal lines represent average force values across the five trials for each limb.

Table 1

Comparison of demographics, anthropometrics, and outcome measures between groups

Characteristic	OA	CTL	<i>p</i> - value
Sex	Women n = 30 Men n = 20	Women n = 8 Men n = 9	0.258
Age (year)	64.1 ± 8.4	66.8 ± 6.5	0.226
Body Mass (kg)	87.1 ± 17.7	79.8 ± 15.4	0.137
Body Height (cm)	169.0 ± 9.6	170.6 ± 9.1	0.545
Weight-bearing Asymmetry			
Vertical GRF during FTSST (ASI)	18.0 ± 14.4	9.0 ± 6.9	0.015
Knee Impairment Measures			
Knee pain during FTSST (NPRS 0-10)	3.0 ± 2.74	N/A†	
Knee extensor strength asymmetry (ASI)	31.8 ± 23.2	8.3 ± 7.8	<0.001
Knee flexion motion asymmetry (ASI)	8.4 ± 7.5	1.8 ± 1.3	<0.001
Knee extension motion asymmetry (ASI)	3.4 ± 2.8	0.7 ± 0.8	<0.001
Physical Function Measures			
FTSST (s)	13.3 ± 3.7	9.9 ± 1.4	<0.001
6MWT (m)	440.2 ± 102.1	600.1 ± 76.1	<0.001
SCT (s)	18.5 ± 8.5	8.9 ± 1.7	<0.001

NOTE. Values are mean ± SD except for sex, which is presented as number of women and men.

* No knee pain was reported by any of the CTL group participants.

Abbreviations: OA, osteoarthritis group; CTL, control group; ASI, Absolute Symmetry Index; FTSST, Five Times Sit-to-Stand Test; NPRS, Numerical Pain Rating Scale; PROM, Passive Range of Motion; 6MWT, Six-Minute Walk Test; SCT, Stair Climb Test.

Table 2

Pearson product-moment correlations between weight-bearing asymmetry and outcome measures

	Correlation with v-GRF SR (<i>r</i> value)		
		lower 95% CI	upper 95% CI
FTSSTVASI	-0.34	-0.56	-0.06
RATIO EXT TORQ	0.37	0.10	0.59
RATIO ROM ext	-0.16	-0.43	0.13
KNEE ROM flex	-0.03	-0.32	0.25
FTSSTt	-0.44	-0.64	-0.18
6MWd	0.29	0.01	0.52
SCTt	-0.39	-0.60	-0.12

Abbreviations: v-GRF, vertical ground reaction force; SR, symmetry ratio; *r* value, Pearson product-moment correlation value; NPRS, numeric pain rating scale.