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Research Report

Clinical Tests of Standing Balance in the Knee Osteoarthritis Population: Systematic Review and Meta-analysis

Gillian L. Hatfield, Adam Morrison, Matthew Wenman, Connor A. Hammond, Michael A. Hunt

G.L. Hatfield, PT, PhD, Department of Physical Therapy, University of British Columbia, Vancouver, British Columbia, Canada.

A. Morrison, PT, Department of Physical Therapy, University of British Columbia.

M. Wenman, PT, Department of Physical Therapy, University of British Columbia.

C.A. Hammond, BSc, Department of Physical Therapy, University of British Columbia.

M.A. Hunt, PT, PhD, Department of Physical Therapy, University of British Columbia, 212 Friedman Bldg, 2177 Wesbrook Mall, Vancouver, British Columbia, Canada V6T 1Z3. Address all correspondence to Dr Hunt at: michael.hunt@ubc.ca.

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Background. People with knee osteoarthritis (OA) have a high prevalence of falls. Poor standing balance is one risk factor, but the extent of standing balance deficits in people with knee OA is unknown.

Purpose. The primary purpose of this study was to summarize available data on standing balance in people with knee OA compared with people without knee OA. A secondary purpose was to establish the extent of balance impairment across disease severity.

Data Sources. A literature search of the MEDLINE, EMBASE, CINAHL, and Web of Science databases through November 19, 2014, was conducted.

Study Selection. Studies on individuals with knee OA containing clinical, quantifiable measures of standing balance were included. Methodological quality was assessed by 2 reviewers using a 16-item quality index developed for nonrandomized studies. Studies scoring >50% on the index were included.

Data Extraction. Participant characteristics (age, sex, body mass index, OA severity, compartment involvement, unilateral versus bilateral disease) and balance outcomes were extracted by 2 reviewers. Standardized mean differences were pooled using a random-effects model.

Data Synthesis. The search yielded 2,716 articles; 8 met selection and quality assessment criteria. The median score on the quality index was 13/17. People with knee OA consistently performed worse than healthy controls on the Step Test, Single-Leg Stance Test, Functional Reach Test, Tandem Stance Test, and Community Balance and Mobility Scale. The pooled standardized mean difference was −1.64 (95% confidence interval=−2.58, −0.69). No differences were observed between varying degrees of malalignment, or between unilateral versus bilateral disease.

Limitations. No studies compared between-knee OA severities. Thus, expected changes in balance as the disease progresses remain unknown.

Conclusions. Few studies compared people with knee OA and healthy controls, but those that did showed that people with knee OA performed significantly worse. More research is needed to understand the extent of balance impairments in people with knee OA using easy-to-administer, clinically available tests.

Knee osteoarthritis (OA) is a progressive joint disease that results in the degradation of articular cartilage and changes in the subchondral bone.[1] However, although articular cartilage degradation and subchondral bone changes are hallmarks of the disease and are typically used to grade disease severity, knee OA affects the entire synovial joint. Changes also are observed in the ligaments, periarticular muscle, nerves, and menisci.[2] Knee OA leads to pain, stiffness, muscle strength deficits, and joint instability, with the long-term effects reducing an individual's functional mobility. These mobility limitations can result in an increased risk of cardiovascular disease, poor quality of life, and loss of function.[3] Specifically, knee OA results in more difficulty with activities of daily living, such as walking and climbing stairs, than any other medical condition for adults over the age of 65 years.[4]

A high prevalence of falls is one factor that contributes to the mobility limitations and difficulties with activities of daily living in this group. Levinger et al[5] found that almost 50% of adults with severe knee OA had experienced a fall in the previous year, and Williams et al[6] reported that, in women, this number increased to two-thirds of those surveyed. In healthy older adults, 32% of those who have fallen will require help with activities of daily living after the fall and will expect to need help for 6 months.[7] Thus, there is a need to address the risk of falls in the conservative management and monitoring of people with knee OA.

Poor balance control, especially during standing or movement, is one risk factor for falls that could be addressed in the knee OA population. Balance consists of maintaining, achieving, or restoring the center of mass within the base of support[8,9]; the control of which is multidimensional. It is dependent on the task characteristics, as well as the environment in which these tasks are performed.[9] In those with knee OA, balance also is affected by variables such as muscle strength, radiographic severity, knee alignment, pain, and proprioceptive acuity. Better standing balance has been associated with increased quadriceps muscle strength, more advanced radiographic disease severity, less varus alignment, less pain, and better proprioception.[10,11] Due to the multidimensional nature of standing balance control, there are a variety of tools that can be used to assess it. In the clinical setting, these tools need to be relatively simple, inexpensive, and easy to administer (ie, requiring minimal equipment) in order to identify those who are at risk for falls and to monitor the effect of treatment. The tools also must be reliable and valid. These tests typically rate performance across a variety of motor tasks or use a stopwatch to time how long a patient can maintain balance in a specific posture.[12]

Given the elevated risk of falls and eventual fall rates in people with knee OA, it is important to establish the extent of balance impairment in this population. Therefore, the purpose of this systematic review and meta-analysis was to summarize the available data on standing balance impairment in people with knee OA compared with people without knee OA, using clinically available tests. A secondary purpose was to establish the extent of balance impairment across disease severities.

Method

Data Sources and Searches

A search strategy was devised for the following databases: MEDLINE (OvidSP and PubMed), EMBASE, CINAHL, and Web of Science. It contained: (1) osteoarthritis, knee, (2) knee joint, (3) osteoarthritis, (4) combined 2 AND 3, (5) (knee* adj3 osteoarthrit*).mp, (6) 1 OR 4 OR 5, (7) Postural Balance, (8) (balance* OR equilibrium OR stabilit*).mp, (9) 7 OR 8, (10) (measure* OR assess* OR evaluat*).mp, (11) outcome assessment (health care), (12) 10 OR 11, and (13) 6 AND 9 AND 12. The final literature search was conducted on November 19, 2014. The abstracts of all returned titles were reviewed by 2 reviewers (A.M. and M.W.). Full-text versions of articles meeting the selection criteria were obtained for inclusion in this review. Reference lists of included articles were hand searched to ensure all eligible articles were included, and once the main clinical tests of standing balance were identified, an additional targeted search for studies using these tests was performed. This consisted of a key word search using the term "knee osteoarthritis" and the name of the clinical balance test.

Study Selection

Two reviewers (A.M. and M.W.) independently reviewed the full-text articles to determine eligibility to proceed to the quality assessment. Publications were required to be human-based studies examining clinical tests of standing balance in people with radiographically diagnosed knee OA. A clinical test of standing balance was defined as a test that quantifies one or more aspects of standing balance but does not require specialized equipment other than that commonly available at most physical therapy clinics (eg, a stopwatch or measuring tape, but not a force platform or swaymeter) and provides a numeric estimate of performance. Studies were not limited to include only participants with a specific knee OA severity, compartment involvement, or alignment (ie, as long as the study included participants with knee OA, it could be included). Studies were excluded if they: (1) used a nonclinical measure of standing balance (ie, force platform or swaymeter), (2) contained participants with radiographically confirmed OA in other weight-bearing joints, (3) contained participants who had undergone total joint arthroplasty in the study limb, (4) contained participants who required the use of a walking aid, (5) did not have a comparison group (either healthy older adults or individuals with differing knee OA severities, alignments, and so on), (6) were review articles, or (7) were not available in English.

In studies where participants underwent an intervention, only preintervention data were included in this review. Included publications from the same authors were searched on the basis of participant characteristics to ensure there was no bias introduced through duplicate data. If multiple publications were authored by the same authors and presented outcome measures from the same participant sample (ie, same participant numbers, age, mass, and sex ratio),

only balance data from the publication with the higher methodological quality were included in the review. If point estimates of the balance measures (ie, mean and standard deviation) were not included in an article, the corresponding author of the publication was contacted. Articles were excluded if the authors did not respond to the request for additional information.

Quality Assessment and Data Extraction

Two independent reviewers (G.L.H. and C.A.H.) assessed and extracted data from all articles. Methodological quality of articles passing the "study selection" stage was assessed using a modified version[13] of a validated quality index for nonrandomized trials.[14] The modified version contained 16 items assessing reporting quality (7 items), external validity (2 items), and internal validity (bias and confounding) (7 items). It did not contain items related to intervention validity but still contained items related to blinding of observers. Studies that scored less than 50% (<9 points out of 17) on the quality assessment were excluded from further review.[15] In the case of disagreements of the initial ratings from the independent reviewers, a third assessor (M.A.H.) was asked to rate the study in question, and consensus was reached among the assessors. As the kappa statistic can be affected by the prevalence of the findings, resulting in low values that do not necessarily reflect the level of agreement between observers,[16] interrater agreement was assessed by calculating positive and negative agreement for each item of the quality assessment index.[17]

Publication details (author, year, and publication source and type), sample characteristics (sample size, source of participants, and selection criteria), participant characteristics (age, sex, body mass index, knee OA severity, compartment affected, and unilateral versus bilateral disease), and balance outcome (measure used, method, result mean and standard deviation, and *P* values) were extracted from each study. We also extracted data relating to other variables that have previously been linked to balance deficits in people with knee OA,[10,11] as were available: muscle strength, knee frontal-plane alignment, pain, and proprioceptive acuity.

Data Synthesis and Analysis

A standardized mean difference (SMD, mean difference/pooled standard deviation, Hedges corrected for bias) and 95% confidence interval (95% CI) were calculated for each study to quantify the magnitude of the difference between groups (either between those with knee OA and healthy controls or among those with varying knee OA severities, alignments, limb involvement, and so on) and to allow for comparison among different outcome measures. The magnitude of the SMD was classified using the criteria of Hopkins et al,[18] where trivial was 0.0 to 0.2, small was 0.21 to 0.6, moderate was 0.61 to 1.2, and large was greater than 1.2.

Meta-analysis of the balance differences between those with knee OA and healthy controls was performed using the SMD in a random-effects model within Cochrane Review Manager (RevMan, version 5.3, Copenhagen, Denmark: The Nordic Cochrane Centre, The Cochrane Collaboration), using the I^2 index to measure inconsistency (the percentage of total variation due to heterogeneity) across the included articles. I^2 values of 30% to 60% represent moderate heterogeneity, values of 50% to 90% may represent substantial heterogeneity, and values of 75% to 100% may represent considerable heterogeneity, according to Deeks et al.[19] If a study provided data from more than one clinically available test of standing balance, we extracted data from the balance test that was highest on the following list:

1. Community Balance and Mobility Scale
2. Berg Balance Scale
3. Functional Reach Test
4. Single-Leg Stance Test
5. Step Test
6. Tandem Stance Test

The Community Balance and Mobility Scale and Berg Balance Scale were at the top of the list, as they are multitask balance tests that challenge a variety of standing balance abilities. The Community Balance and Mobility Scale was ranked higher due to the established ceiling effect of the Berg Balance Scale.[20–22] The Functional Reach Test and Single-Leg Stance test were included next due to their established reliability in the knee OA population[20,23] and ability to predict falls in older adults.[24,25] Reliability and validity for the Step Test and Tandem Stance Test have not been reported for people with knee OA, but the Step Test was included higher on the list because it has been found to be reliable in healthy older adults poststroke.[26]

Role of the Funding Source

No operating funds were used for this study. Salary support was provided by the Canadian Institutes of Health Research (G.L.H.) and the Michael Smith Foundation for Health Research (M.A.H.).

Results

Search Strategy and Study Characteristics

The search strategy resulted in 2,716 unique articles, of which 12 passed the full-text screening. A targeted literature search resulted in 4 additional articles, leaving 16 articles to undergo quality assessment. Eight articles that did not meet our predetermined methodological quality threshold values were excluded; thus, 8 articles were included in the review (Fig. 1). Five studies compared outcomes of clinical tests of standing balance between knee OA and healthy older adult groups, 2 studies reported outcomes of clinical tests of standing balance for participants with differing amounts of varus alignment, and 1 study compared people with unilateral knee OA and those with bilateral knee OA (Tab. 1). All but 2 studies reported participant radiographic disease severity according to the Kellgren-Lawrence (KL) scale.[27] For one study, radiographic severity was assessed using the Ahlbäck classification,[28] and for the other study, radiographic severity data were not available (it was just stated that participants had radiographically confirmed knee

OA).[29] All studies grouped participants with a range of KL scores into one "knee OA" group; no studies examined the association between knee OA severity and clinical tests of standing balance.

Methodological Quality

Quality assessment scores of the 8 included articles ranged from 11 to 14 (out of a maximum of 17) points, with a median score of 13, which was interpreted as moderate-to-high methodological quality (Tab. 2). Based on the initial quality assessments, interobserver agreement was excellent, with positive agreements ranging from 0.92 to 1.00. Consensus was reached on all differing items during the first discussion. Items 11 and 12 were only met in 1 of the 8 articles and were related to external validity, specifically whether individuals asked to participate were representative of the entire population (item 11) and whether those who chose to participate were representative of the entire population (item 12). Because the majority of studies recruited participants from specialized clinical populations, they were not necessarily representative of the knee OA population as a whole.

Clinically Available Tests of Standing Balance

Within the 8 articles selected for this review, 6 clinical tests of standing balance were included: (1) Step Test (4 studies[30–33]), (2) Berg Balance Scale (2 studies[20,28]), (3) Single-Leg Stance Test (2 studies[28,29]), (4) Functional Reach Test (2 studies[28,29]), (5) Tandem Stance Test (1 study[34]), and (6) Community Balance and Mobility Scale (1 study[20]).

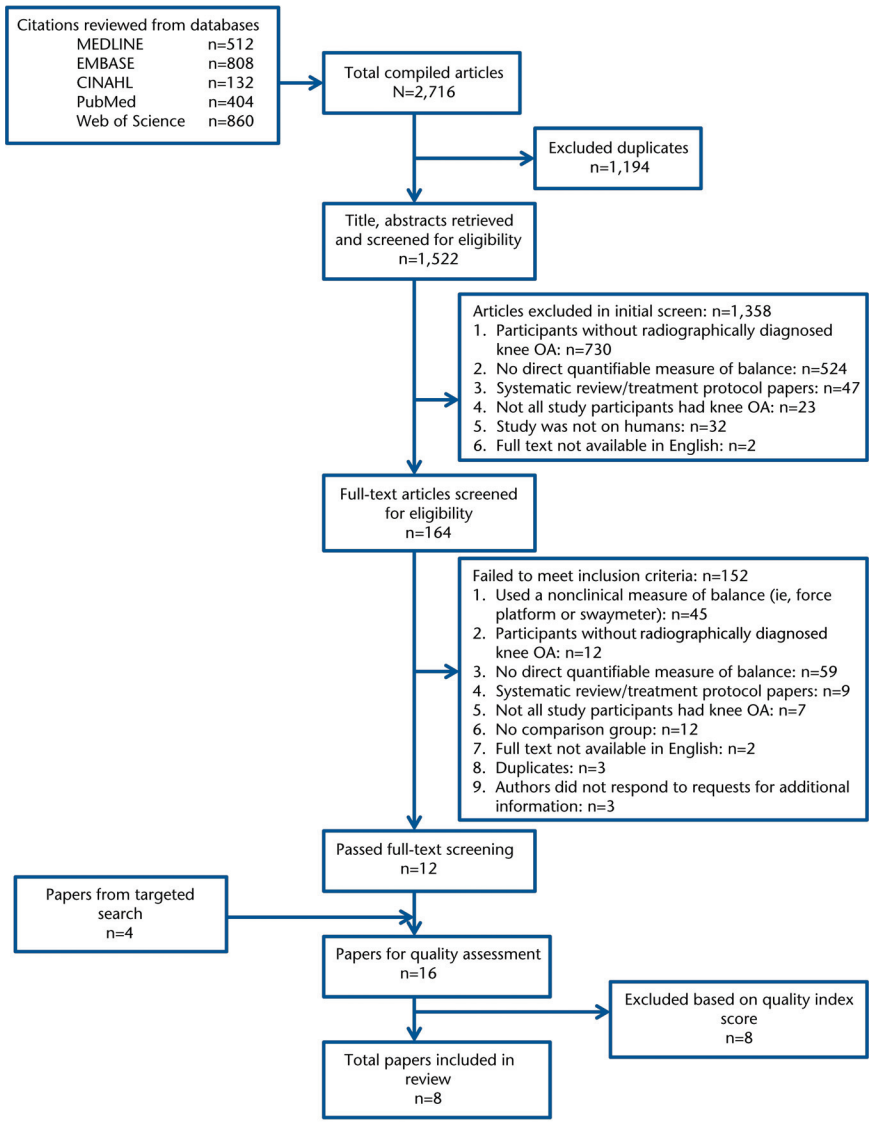

Figure 1.
Flow diagram of search strategy. OA=osteoarthritis.

Step Test. Four studies used the Step Test as a clinical test of standing balance (Tab. 3), with 2 studies comparing participants with knee OA with healthy controls[30,31] and 2 studies comparing knee OA groups with different varus alignments.[32,33] For this test, the participant maintains balance on the study limb while stepping on and off of a 15-cm step with the contralateral foot as many times as possible within 15 seconds. For those with knee OA, performance ranged from 12 to 14 steps in 15 seconds. Only one study published point estimates for data between participants with knee OA and healthy controls, where performance was 12 and 17 steps, respectively (a large SMD of −3.29; 95% CI=−4.08, −2.50).[31] The other article containing data for people with knee OA and healthy controls also showed that healthy controls were able to complete 5 more steps in the 15 seconds than the knee OA group but did not provide point estimates. After contacting the author, these values were provided. The healthy controls completed an average of 17.1 steps in 15 seconds, and the knee OA group completed an average of 12.1 steps, a large SMD of −1.54 (95% CI=−2.09, −0.98).[30] There was a small SMD between varus alignment groups, and differences in performance did not reach statistical significance.[32,33]

Berg Balance Scale. Two studies used the Berg Balance Scale as a clinical test of standing balance, with both studies comparing participants with knee OA and healthy controls.[20,28] This test consists of 14 tasks testing static and dynamic balance. Each task is scored on a 0 (unable to perform or needs assistance) to 4 (able to perform independently) scale, with a maximum score of 56. For people with knee OA, performance ranged from 50 to 56 out of 56. One study showed a signif-

Table 1.
Studies Included in Review[a]

Study	Comparison	Sample Size Total (F/M)	Group Demographics $\bar{X}$ (SD)	OA Severity (Frequency)	OA Characteristics $\bar{X}$ (SD)
Adegoke et al,[29] 2012	Unilateral vs bilateral	N=52 46 F, 6 M	Unilateral (n=25): Age: 59.7 (9.9) y BMI: 31.8 (6.8) kg/m^2 Bilateral (n=27): Age: 58.3 (9.8) y BMI: 31.1 (4.3) kg/m^2	Not available	Compartment: not available 25 unilateral, 27 bilateral Strength: not available Alignment: not available Pain: 6.36/10 (1.35) unilateral, 7.11/10 (1.25) bilateral Proprioception: not available
Hinman et al,[30] 2002	Healthy control	N=66 32 F, 34 M Knee OA: n=33; 16 F, 17 M Healthy control: n=33; 16 F, 17 M	 Knee OA: Age: 68.1 (8.6) y BMI: 28.6 (3.3) kg/m^2 Healthy control: Age: 68.1 (8.0) y BMI: 27.5 (5.0) kg/m^2	18% KL1 or KL2 82% KL3 or KL4	Compartment: not available Unilateral vs bilateral: not available Strength: not available Alignment: not available Pain: 5.0/10 (1.6) Proprioception: not available
Kim et al,[34] 2010	Healthy control, M vs F	N=504 274 F, 230 M Knee OA: n=188; 152 F, 36 M Healthy control: n=316	Age: 70.2 y	KL ≥2 in all participants with OA	Compartment: not available Unilateral vs bilateral: not available Strength: not available Alignment: not available Pain: not available Proprioception: not available
Lim et al,[32] 2008	Least varus vs moderate varus vs most varus alignment	N=107 59 F, 48 M Least varus: n=37; 24 F, 13 M Moderate varus: n=36; 21 F, 15 M	 Least varus: Age: 62.0 (8.9) y BMI: 28.6 (5.3) kg/m^2 Alignment: 0.5 (1.6)° Moderate varus: Age: 63.5 (7.8) y BMI: 29.2 (5.1) kg/m^2 Alignment: 4.2 (1.1)°	 Least varus: KL 2=23, KL 3=8, KL 4=6 Moderate varus: KL 2=9, KL 3=15, KL 4=12	Medial compartment knee OA Least varus: 20 unilateral, 17 bilateral Strength: Quads: 1.22 (0.53) N·m/kg, Hams: 0.67 (0.31) N·m/kg Pain: 34.9/100 (16.3) Proprioception: not available Moderate varus: 24 unilateral, 12 bilateral Strength: Quads: 1.30 (0.58) N·m/kg, Hams: 0.68 (0.29) N·m/kg Pain: 35.7/100 (14.6) Proprioception: not available

(*Continued*)

Table 1.
Continued

Study	Comparison	Sample Size Total (F/M)	Group Demographics $\bar{X}$ (SD)	OA Severity (Frequency)	OA Characteristics $\bar{X}$ (SD)
Lim et al,[32] 2008 (continued)		Most varus: n=34; 14 F, 20 M	Most varus: Age: 68.5 (7.5) y BMI: 29.2 (4.2) kg/m^2 Alignment: 7.7 (1.7)°	Most varus: KL 2=2, KL 3=6, KL 4=26	Most varus: 22 unilateral, 12 bilateral Strength: Quads: 1.45 (0.49) N·m/kg, Hams: 0.78 (0.24) N·m/kg Pain: 36.5/100 (14.6) Proprioception: not available
Lim et al,[33] 2008	More varus vs more neutral alignment (baseline data from intervention study)	N=107 59 F, 48 M			Medial compartment knee OA
		Strengthening group: n=53; 30 F, 23 M More varus: n=26; 13 F, 13 M	Strengthening group: More varus: Age: 67.2 (6.7) y BMI: 28.2 (3.7) kg/m^2 Alignment: 6.7 (1.7)°	Strengthening group: More varus: KL 2=4, KL 3=8, KL 4=18	Strengthening group: More varus: 15 unilateral, 11 bilateral Strength: Quads: 1.38 (0.52) N·m/kg Pain: 33.1/100 (15.4) Proprioception: not available
		More neutral: n=27; 17 F, 10 M	More neutral: Age: 64.1 (9.3) y BMI: 29.0 (5.2) kg/m^2 Alignment: 1.2 (1.9)°	More neutral: KL 2=12, KL 3=7, KL 4=8	More neutral: 18 unilateral, 9 bilateral Strength: Quads: 1.32 (0.57) N·m/kg Pain: 35.7/100 (14.6) Proprioception: not available
		Control group: n=54; 29 F, 25 M More varus: n=26; 12 F, 14 M	Control group: More varus: Age: 66.6 (8.9) y BMI: 30.3 (5.3) kg/m^2 Alignment: 6.9 (2.0)°	Control group: More varus: KL 2=3, KL 3=4, KL 4=19	Control group: More varus: 18 unilateral, 8 bilateral Strength: Quads: 1.46 (0.54) N·m/kg Pain: 39.2/100 (14.0) Proprioception: not available
		More neutral: n=28; 17 F, 11 M	More neutral: Age: 60.8 (7.8) y BMI: 28.4 (5.0) kg/m^2 Alignment: 1.6 (1.8)°	More neutral: KL 2=15, KL 3=10, KL 4=3	More neutral: 15 unilateral, 13 bilateral Strength: Quads: 1.12 (49) N·m/kg Pain: 34.6/100 (16.2) Proprioception: not available

(*Continued*)

Table 1.
Continued

Study	Comparison	Sample Size Total (F/M)	Group Demographics $\bar{X}$ (SD)	OA Severity (Frequency)	OA Characteristics $\bar{X}$ (SD)
Mohammadi et al,[31] 2008	Healthy control	N=60 Knee OA: n=30 F Healthy control: n=30 F	Knee OA: Age: 46.4 (5.1) y BMI: 27.1 (3.3) kg/m² Healthy control: Age: 45.5 (4.9) y BMI: 26.9 (4.3) kg/m²	15% mild OA (KL 1 or 2) 85% severe OA (KL 3 or 4)	Compartment: not available Unilateral vs bilateral: not available Strength: Quads: 13.7 kg Alignment: not available Pain: 4.3/10 (1.2) Proprioception: 2.5° angular error
Sun et al,[28] 2006	Healthy control	N=106 Knee OA: 56 21 F, 35 M Healthy control: 50 19 F, 31 M	Knee OA: Age: 74.7 (5.4) y BMI: 27.3 (4.1) kg/m² Healthy control: Age: 73.8 (5.5) y BMI: 27.2 (4.0) kg/m²	Ahlbäck classification: Grade 1: 26 Grade 2: 30	Compartment: not available Unilateral knee OA Strength: not available Alignment: not available Pain: 5.4/10 (2.4) Proprioception: not available
Takacs et al,[20] 2014	Healthy control	N=50 Knee OA: 25 14 F, 11 M Healthy control: 25 14 F, 11 M	Knee OA: Age: 62.5 (7.4) y BMI: 29.2 (6.6) kg/m² Healthy control: Age: 63.3 (6.2) y BMI: 24.6 (4.0) kg/m²	Knee OA: KL 0=0, KL 1=0, KL 2=14, KL 3=9, KL 4=2 Healthy control: KL 0=11, KL 1=14, KL 2=0, KL 3=0, KL 4=0	Medial compartment knee OA Unilateral vs bilateral: not available Strength: not available Alignment: not available Pain: 3.3/10 (2.4) Proprioception: not available

[a] F=female, M=male, OA=osteoarthritis, BMI=body mass index, KL=Kellgren-Lawrence scale score, Quads=quadriceps muscles, Hams=hamstring muscles.

icant between-group difference (participants with knee OA scored 50/56 compared with 53/56 for healthy controls),[28] but the other study showed no between-group difference, with both groups having a median score of 56/56 (range=53–56).[20] These scores corresponded to SMDs of −0.71 (95% CI=−1.10, −0.31) (moderate),[28] and 0,[20] respectively.

Single-Leg Stance Test. Two studies used the Single-Leg Stance Test as a clinical test of standing balance, with both studies making comparisons between people with knee OA and healthy controls.[20,28] For this test, participants maintain unilateral stance on the study limb without touching the free limb to the ground or performing excessive trunk or upper body movements for the duration. Eyes remain open. Two or 3 attempts are given (depending on the study), and the maximum time among the attempts is recorded. Performance in the participants with knee OA was significantly worse than in the healthy controls, ranging from 24 to 42 seconds (versus 50–66 seconds in the healthy controls), a moderate SMD of 0.63 to 0.76.[20,28]

Functional Reach Test. Two studies used the Functional Reach Test to quantify standing balance in people with knee OA. One study compared people with knee OA and healthy controls,[28] and the other study compared unilateral and bilateral disease.[29] For this test, participants stand next to a measuring stick mounted on a wall with their feet 10 cm apart. They make a fist on their dominant arm and flex this arm at the glenohumeral joint so that the arm is parallel to the floor. Participants then reach their dominant arm forward as far as possible without touching the wall or taking a step. The distance the participant can reach forward beyond arm's length is then recorded. Performance ranged from 23 to 38 cm for people with knee OA. In the study comparing people with knee OA and healthy controls, people with knee OA were able to reach 23 cm (versus 29 cm for the healthy controls), a large SMD of −1.32 (95% CI=−1.73, −0.89).[28] No significant differences were seen between participants with unilateral and bilateral knee OA (SMD=0.07).[29]

Table 2.
Modified Quality Index[a]

Study	Reporting Quality							External Validity		Internal Validity–Bias				Internal Validity–Confounding			Total (17)
	1. Hypothesis clearly described?	2. Main outcomes clearly described?[b]	3. Characteristics of the participants included clearly described?[c]	5. Distribution of principal confounder of each group clearly described?[d]	6. Main findings clearly described?	7. Estimates of random variability provided for the main outcomes?	10. Actual probability values reported for main outcomes?[e]	11. Were the participants asked to participate representative of the entire population?	12. Were the participants who were prepared to participate representative of the entire population?	15. Was there an attempt to blind those measuring the main outcomes?	16. Was it clear if the results were based on "data dredging"?	18. Were the statistical tests appropriate?	20. Were the main outcome measures valid and reliable?	21. Were all participants and controls recruited from the same population?	22. Were all participants and controls recruited over the same time period?	25. Was there adequate adjustment for confounding?	
Adegoke et al,[29] 2012	1	1	0	1	1	1	1	0	0	0	1	1	1	1	0	1	11
Hinman et al,[30] 2002	1	1	1	2	0	0	1	0	0	0	1	1	1	1	0	1	11
Kim et al,[34] 2010	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	13
Lim et al,[32] 2008	1	1	1	2	1	1	0	0	0	1	1	1	1	1	1	1	14
Lim et al,[33] 2008	1	1	1	2	1	1	1	0	0	0	1	1	1	1	1	1	14
Mohammadi et al,[31] 2008	1	1	1	2	1	1	1	0	0	1	1	1	1	1	0	1	14
Sun et al,[28] 2006	1	1	1	2	1	1	1	0	0	1	1	1	1	0	0	1	13
Takacs et al,[20] 2014	1	1	1	2	1	1	1	0	0	0	1	1	1	1	0	1	13
Positive agreement	1	1	0.92	0.93	1	1	1	1	1	1	1	1	1	1	1	1	
Negative agreement	0	0	0.67	0	1	1	1	1	1	1	0	0	0	1	1	0	

[a] All items, except item 5, were scored 1 for fulfilling the criterion or 0 if the criterion were not filled. Publications that did not provide sufficient details to fulfill the criterion also were given a score of 0 for "unable to be determined," as per instructions of the original index. Positive and negative agreements indicate level of initial agreement between reviewers prior to the consensus meeting.
[b] Studies had to report the outcome measure in the Method section, including a brief description of how to administer to receive a score of 1.
[c] Studies had to report age, sex, height and weight, or body mass index and severity of all groups to receive a score of 1.
[d] Studies had to report age, sex, body mass index for all groups and radiographic severity for knee osteoarthritis groups to receive full marks; a score of 1 was given if partially reported.
[e] Actual P values (unless $<.01$) had to be reported to receive a score of 1.

Table 3.
Results of Included Articles[a]

Study	Knee OA	Comparator	Result[b]	Mean Difference (95% CI) and/or Significance	SMD
Step Test (number of steps in 15 s)					
Hinman et al,[30] 2002	18% KL1 or KL2 82% KL3 or KL4	Healthy control	Knee OA: 12.1 (3.5) Healthy control: 17.1 (2.9)	$P<.001$	SMD=−1.56
Lim et al,[32] 2008	Most varus: KL 2=2, KL 3=6, KL 4=26	Least varus: KL 2=23, KL 3=8, KL 4=6 Moderate varus: KL 2=9, KL 3=15, KL 4=12	Least varus: 13 (3) Moderate varus: 13 (3) Most varus: 14 (4)	$P=.063$	Least vs moderate varus: SMD=0 Least vs most varus: SMD=0.29 Moderate vs most varus: SMD=0.29
Lim et al,[33] 2008	Strengthening group: More varus: KL 2=4, KL 3=8, KL 4=18 More neutral: KL 2=12, KL 3=7, KL 4=8	Control group: More varus: KL 2=3, KL 3=4, KL 4=19 More neutral: KL 2=15, KL 3=10, KL 4=3	Baseline values: Strengthening group: More varus: 13 (3) More neutral: 12 (3) Control group: More varus: 14 (3) More neutral: 13 (3)	$P>.05$	Strengthening group: SMD=0.33 Control group: SMD=0.33
Mohammadi et al,[31] 2008	15% mild OA (KL 1 or 2) 85% severe OA (KL 3 or 4)	Healthy control	Knee OA: 12 (1.5) Healthy control: 17 (1.5)	$P<.001$	SMD=−3.33
Berg Balance Scale (/56)					
Sun et al,[28] 2006	Ahlbäck classification: Grade 1: 26 Grade 2: 30	Healthy control	Knee OA: 50.03 (5.38) Healthy control: 53.20 (3.11)	$P<.001$	SMD=−0.71
Takacs et al,[20] 2014	Knee OA: KL 0=0, KL 1=0, KL 2=14, KL 3=9, KL 4=2	Healthy control: KL 0=11, KL 1=14, KL 2=0, KL 3=0, KL 4=0	Knee OA: 56 (53–56) Healthy control: 56 (53–56)	$P=.09$	SMD=0

(*Continued*)

Table 3.
Continued

Study	Knee OA	Comparator	Result[b]	Mean Difference (95% CI) and/or Significance	SMD
Single-Leg Stance Test (time [s])					
Sun et al,[28] 2006	Ahlbäck classification: Grade 1: 26 Grade 2: 30	Healthy control	Knee OA: 23.94 (41.40) s Healthy control: 50.42 (42.31) s	$P<.001$	SMD=−0.63
Takacs et al,[20] 2014	Knee OA: KL 0=0, KL 1=0, KL 2=14, KL 3=9, KL 4=2	Healthy control: KL 0=11, KL 1=14, KL 2=0, KL 3=0, KL 4=0	Knee OA: 41.7 (33.2) s Healthy control: 66.1 (30.7) s	$P=.01$	SMD=−0.76
Functional Reach Test (distance [cm])					
Adegoke et al,[29] 2012	Unilateral knee OA	Bilateral knee OA	Unilateral: 36.46 (6.79) cm Bilateral: 38.23 (5.17) cm	−1.77 (−5.12, 1.58), $P=.293$	SMD=0.07
Sun et al,[28] 2006	Ahlbäck classification: Grade 1: 26 Grade 2: 30	Healthy control	Knee OA: 22.80 (4.78) Healthy control: 28.81 (4.31)	$P<.001$	SMD=−1.32
Tandem Stance Test (/3)					
Kim et al,[34] 2010	KL ≥2	Healthy control	Men: Knee OA: 0=8.3% 1=13.9% 2=66.7% 3=11.1% Healthy control: 0=5.7% 1=12.9% 2=50.0% 3=31.4%	Men: $P=.093$	No point estimates provided

(*Continued*)

Table 3.
Continued

Study	Knee OA	Comparator	Result[b]	Mean Difference (95% CI) and/or Significance	SMD
Kim et al,[34] 2010 (continued)			Women: Knee OA: 0=7.2% 1=19.7% 2=55.9% 3=17.1% Healthy control: 0=4.9% 1=12.3% 2=44.3% 3=38.5%	Women: P=.001	
Community Balance and Mobility Scale (/96)					
Takacs et al,[20] 2014	Knee OA: KL 0=0, KL 1=0, KL 2=14, KL 3=9, KL 4=2	Healthy control: KL 0=11, KL 1=14, KL 2=0, KL 3=0, KL 4=0	Knee OA: 71 (13) Healthy control: 85 (10)	P<.001	SMD=−1.21

[a] OA=osteoarthritis, 95% CI=95% confidence interval, SMD=standardized mean difference, KL=Kellgren-Lawrence scale score.
[b] Data presented as mean (SD), except for the study by Takacs et al for which data are presented as mean (range). For all results, higher numbers indicate higher balance ability.

Tandem Stance Test. Only one study used the Tandem Stance Test as a clinical measure of standing balance and compared people with knee OA and healthy controls.[34] Male and female participants were compared separately. In this test, participants are asked to stand with their feet side by side, semitandem, and tandem for 10 seconds each. Participants are scored 0 (able to maintain semitandem stance for <10 seconds), 1 (able to maintain tandem stance for <2 seconds), 2 (able to maintain tandem stance for 3–9 seconds), or 3 (able to maintain tandem for the full 10 seconds). Participants with knee OA performed worse than healthy controls, with 11% of men and 17% of women able to maintain tandem stance for 10 seconds compared with 31% and 39% of men and women without knee OA, respectively, but the difference reached significance only for women.

Community Balance and Mobility Scale. One study used the Community Balance and Mobility Scale as a clinical test of balance and compared people with knee OA and healthy controls.[20] This test consists of 13 tasks, including bending, turning or looking while walking, single-leg stance, and stair descent, and is scored out of 96 points. Each task is graded 0 (unable to perform) to 5 (proficient), except for stair descent, which is scored out of 6 points. Participants with knee OA performed significantly worse than healthy controls (71 versus 85 out of 96, respectively), a moderate SMD of −1.19 (95% CI=−1.79, −0.58).

Meta-Analysis

Standardized mean differences for 4 studies comparing people with knee OA and healthy older adults are included in the forest plot shown in Figure 2. Data from the study by Kim et al[34] were not included, as point estimates for the tandem stance test were not provided and the SMD could not be calculated. Pooled data indicated that participants with knee OA had balance deficits compared with healthy older adults, with a pooled SMD of −1.64 (95% CI=−2.58, −0.69). There was evidence of considerable heterogeneity,[19,35] indicated by the I^2 value of 91%. A sensitivity analysis was conducted, excluding a potentially outlying

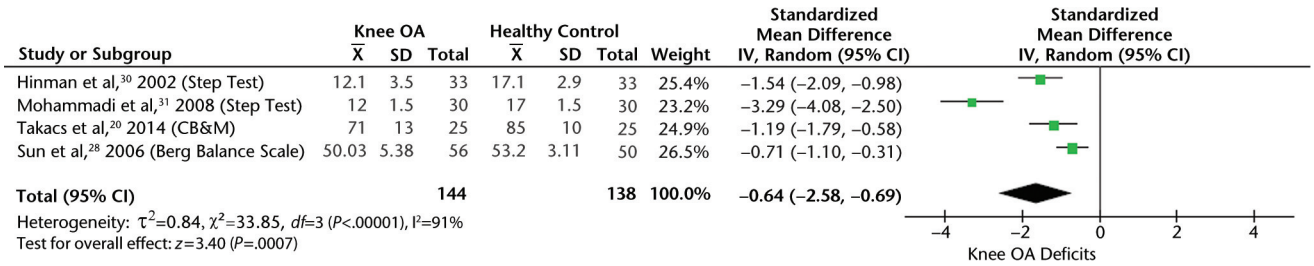

Figure 2.
Forest plot depicting standardized mean differences between participants with knee OA and healthy older adults for studies included in the review. Negative standardized mean differences indicate worse balance outcomes in the knee OA group. OA=osteoarthritis, IV=inverse variance, 95% CI=95% confidence interval, CB&M=Community Balance and Mobility Scale.

study,[31] resulting in a reduction in the SMD to −1.11 (95% CI=−1.63, −0.60) and a reduction in the between-study heterogeneity to substantial (I^2=67%).

Discussion

The primary purpose of this systematic review was to summarize the available data on standing balance impairment using clinically available measures in people with knee OA compared with those without knee OA. Only 5 studies compared participants with knee OA with healthy older adults, and it was found that people with knee OA had significantly worse standing balance. Participants with knee OA consistently performed significantly worse on the Step Test, the Single-Leg Stance Test, the Functional Reach Test, and the Community Balance and Mobility Scale. Results for the Berg Balance Scale were equivocal, with 1 of the 2 studies comparing Berg Balance Scale performance between people with knee OA and those without OA finding that people with knee OA had significantly worse balance[28] and the other study finding no significant difference.[20]

When the data were pooled for the studies comparing balance between people with knee OA and healthy older adults, it was confirmed that those with knee OA had significantly poorer balance. The pooled SMD was −1.64. However, considerable study heterogeneity was noted. The high I^2 value was likely due to the variety of standing balance tests used, as well as to possible differences in knee OA severity among the studies. For example, for one study that used the Berg Balance Scale included in the meta-analysis, knee OA severity was graded using the Ahlbäck classification,[28] whereas the other study that used the Berg Balance Scale included knees graded using the KL classification.[20] Therefore, it is difficult to determine the similarity of the groups. The exclusion of an outlying study[31] resulted in a reduction in between-study heterogeneity; however, the participants in that study were similar to those in other studies (mostly severe knee OA, graded using the KL scale). It is probable that the large SMD for that particular study was a result of low variability around the mean in both groups. Despite the study heterogeneity, including and excluding the outlying study, the 95% CI value for the pooled SMD did not cross zero, and the SMD remained moderate to large, indicating that people with knee OA do perform worse on clinical tests of standing balance than healthy controls. The finding that individuals with knee OA generally perform worse than those without knee OA on clinically available balance tests is consistent with studies that used force platforms to quantify standing balance deficits in people with knee OA compared with healthy controls.[36–39]

Although standing balance deficits were consistently found for people with knee OA compared with healthy older adults, a limitation when comparing data for other people with knee OA with the data presented in this review is that not all of the included studies provided data on other variables that are known to be related to balance deficits in people with knee OA, such as quadriceps muscle strength, knee alignment, pain severity, and proprioceptive acuity.[10,11] Thus, the dearth of data for other variables related to balance deficits in knee OA may limit the generalizability of the results.

The secondary purpose of this study was to establish the extent of balance impairment across knee OA disease severities. No studies were identified that compared balance among different radiographic disease severities of knee OA. There was very little research comparing balance in different subpopulations of knee OA. Two studies investigated Step Test scores among knee OA groups of differing varus alignments,[32,33] but no significant between-group differences were found. One study compared Functional Reach Test outcomes between people with unilateral knee OA and those with bilateral involvement but also showed no significant between-group differences. With the paucity of studies comparing different populations of people with knee OA, definitive conclusions regarding balance impairments cannot be made.

Based on the available literature, the most common clinical test of standing balance was the Step Test, used in 4 studies.[30–33] All articles briefly described the testing procedure for this outcome measure, but only 2 studies specified that the participants were barefoot.[30,31] The 2 studies comparing people with knee OA and healthy older adults[30,31] demonstrated a large SMD for the between-group difference, indicating that this clinical test may be a sensitive enough metric for detecting and monitoring standing balance deficits. However, a limitation is that, of the 4 studies that

utilized this outcome measure, 3 were published by the same research group. Thus, the common use in the literature may not reflect widespread use in research or clinical practice.

The Berg Balance Scale,[20,28] Single-Leg Stance Test,[20,28] and Functional Reach Test[28,29] were the second most prevalent clinical tests of balance in the knee OA literature, each used in 2 studies. The Berg Balance Scale is a standardized tool consisting of specific instructions for the tester to say to the participant and specific guidelines regarding scoring. It consists of 14 tasks challenging static and dynamic balance and is widely used in the clinical setting for a variety of patient populations. However, a ceiling effect of the Berg Balance Scale has been well documented for people who can ambulate independently in the community.[20–22] In one study that compared people with knee OA and healthy older adults, the median Berg Balance Scale score for both healthy older adults and those with knee OA was 56—the maximum score possible.[20] In the only other study comparing those with knee OA to healthy older adults included in this review, Sun et al found that Berg Balance Scale scores were significantly lower for people with knee OA,[28] but the difference was only 3 points, less than the minimal detectable change of 4 points for this outcome measure.[40] The similar, high scores by both people with and without knee OA make it difficult to identify those who have standing balance impairments and difficult to assess improvements in balance. Thus, this tool, even though widely used, may not be a sensitive enough clinical test of standing balance, particularly in individuals with knee OA who are higher functioning.

Many of the clinical tests of standing balance used in the literature were single-task tests. This is a limitation because, although these tests are quick and easy to administer, they are of limited value when determining what aspects of balance should be targeted in interventions, as balance is multidimensional. In the case of the Single-Leg Stance Test, Functional Reach Test, and Tandem Stance Test, only static, and not dynamic, balance is challenged. Thus, they may not be adequate tests for examining the dynamic balance requirements necessary for ambulation and independent mobility. The Berg Balance Scale includes a variation of each of the single-task balance tests included in this review, except the Step Test. However, balance deficits between people with knee OA and healthy older adults were unclear using this test due to the ceiling effect. The Community Balance and Mobility Scale is similar to the Berg Balance Scale in that it is a standardized tool consisting of multiple balance tasks. However, it challenges advanced dynamic balance and mobility, including tasks such as quick direction changes and dual tasking. Thus, it may be a more sensitive metric to detect balance deficits. Although only reported in one study in the current review,[20] people with knee OA performed significantly worse than healthy control participants. The SMD was large, indicating that this may be an appropriate tool to use in the clinical setting to detect and monitor balance deficits in people with knee OA.

In conclusion, despite the small number of studies comparing standing balance using clinically available tools in people with knee OA versus healthy older adults, consistent balance deficits were reported. The largest SMDs were seen in the Step Test, the Functional Reach Test, and the Community Balance and Mobility Scale, all of which have been found to be reliable in the knee OA population. When the data were pooled, the SMD for balance deficits was −1.64. Given the elevated risk of falls in people with knee OA, it is important to be able to assess and monitor balance impairments in order to identify individuals most at risk for falling and in order to plan and monitor interventions. More research is needed to fully understand the magnitude of standing balance impairments in people with knee OA (particularly among different disease severities) using easy-to-administer and clinically available tests and to monitor improvements in standing balance during treatment.

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Clinical Tests of Standing Balance in the Knee Osteoarthritis Population: Systematic Review and Meta-analysis

Gillian L. Hatfield, Adam Morrison, Matthew Wenman, Connor A. Hammond and Michael A. Hunt

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