Chapter 3

Association of lower muscle strength with self-reported knee instability in osteoarthritis of the knee: results from the Amsterdam Osteoarthritis cohort

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Abstract

Objective. To determine whether muscle strength, proprioceptive accuracy, and laxity are associated with self-reported knee instability in a large cohort of knee osteoarthritis (OA) patients, and to investigate whether muscle strength may compensate for an impairment in proprioceptive accuracy or laxity, in order to maintain knee stability.

Methods. Data from 283 knee OA patients from the Amsterdam Osteoarthritis cohort were used. Univariable and multivariable logistic regression analyses were performed to assess the association between muscle strength, proprioceptive accuracy (motion sense), frontal plane varus-valgus laxity, and self-reported knee instability. Additionally, effect modification between muscle strength and proprioceptive accuracy and between muscle strength and laxity were determined.

Results. Self-reported knee instability was present in 67% of the knee OA patients and mainly occurred during walking. Lower muscle strength was significantly associated with the presence of self-reported knee instability, even after adjusting for relevant confounding. Impaired proprioceptive accuracy and high laxity were not associated with self-reported knee instability. No effect modification between muscle strength and proprioceptive accuracy or laxity was found.

Conclusion. Lower muscle strength is strongly associated with self-reported knee instability in knee OA patients, while impairments in proprioceptive accuracy and laxity are not. A compensatory role of muscle strength for impaired proprioceptive accuracy or high laxity, in order to stabilize the knee, could not be demonstrated.

Introduction

Knee instability is the sudden loss of postural support across the knee at a time of weight bearing (1). Self-reported knee instability has been operationalized by the sensation of buckling, shifting, or giving way of the knee (1). Approximately 60-80% of patients with knee osteoarthritis (OA) report knee instability (2-6). Knee OA patients reporting knee instability have more severe activity limitations (2;4) than knee OA patients without this sensation. Self-reported knee instability has been linked to higher pain levels (1), higher rates of falling (1), and altered walking patterns (3;5-13), and has been suggested to be a cause of knee OA onset and progression (7;13). Causes of knee instability are still unknown and need to be identified.

Knee instability has been suggested to be a multifactorial problem (1;2;4;14). Biomechanical impairments like muscle weakness, impaired proprioceptive accuracy, and high laxity, which are frequently present in knee OA patients (15-18), have been regularly hypothesized as important causal factors in self-reported knee instability (1;2;4-6;13;14;19). Quadriceps and hamstring muscles are considered to be principal stabilizers of the knee joint by absorbing shock forces and modifying knee joint load (8-10;20-23). Proprioceptive receptors are presumed to be necessary in preventing excessive and possible injurious movements of the knee, by signalling (changes in) the position and motion of the knee joint (19;24). It is also hypothesized that laxity (inadequate passive restraint of the knee) leads to knee instability during dynamic and functional activities (4-6;8;17).

Strong lower limb muscles are suggested as being structures able to stabilize the knee, even when proprioceptive accuracy is impaired or laxity is high (2;8;14;17;19). Studies by van der Esch et al (14;19) in knee OA patients showed that in persons with impaired proprioceptive accuracy or high laxity, muscle strength was more strongly related to activity limitations than in persons with adequate proprioceptive accuracy or low laxity. The authors suggested that strong muscles around the knee can compensate for impaired proprioceptive accuracy or high laxity, in order to maintain knee stability, thereby resulting in less severe activity limitations.

Recently, a few studies have focused on the associations between biomechanical factors (muscle strength, proprioceptive accuracy, and laxity) and self-reported knee instability in knee OA patients (3;4;6;13;25). One study (25) in 38 knee OA patients showed that proprioceptive accuracy (position sense) was associated with self-reported knee instability. Two small knee OA studies (4;13) (*n*=52 and *n*=20, respectively) found no association between muscle strength and self-reported knee instability. Laxity was not associated with self-reported knee instability in 4 small knee OA studies (study populations ranged from 15-52) (3;4;6;13). A large population-based study with more than 2,000 participants (but not exclusively persons with knee OA) demonstrated an association between lower muscle strength and a higher presence of knee buckling (1). Associations between biomechanical factors and self-reported instability have not been determined in a large knee OA cohort.

This study therefore aims to determine the associations between muscle strength, proprioceptive accuracy, laxity, and self-reported knee instability in a large knee OA cohort. Second, we will investigate whether muscle strength can compensate for an impairment in proprioceptive accuracy or laxity, in order to maintain knee stability.

Patients and methods

Subjects

Data from the Amsterdam Osteoarthritis (AMS-OA) cohort were used for this study. The AMS-OA is a cohort of patients with osteoarthritis of the knee and/or hip according to the American College of Rheumatology criteria (26;27) who have been referred to a rehabilitation center (Reade, center for rehabilitation and rheumatology, Amsterdam, The Netherlands). Total knee replacement, rheumatoid arthritis or any other form of arthritis (i.e., crystal arthropathy, septic arthritis, spondylarthropathy) were exclusion criteria. Patients were subsequently assessed by rheumatologists, radiologists and rehabilitation physicians. The measurement protocol contained the assessment of demographic, radiographic, biomechanical, clinical, and psychosocial factors related to OA, which were all assessed prior to any treatment. Participants diagnosed with knee OA and providing written informed consent were included for this study. The study was approved by the Slotervaart Hospital/ Reade Institutional Review Board.

Measures

Self-reported knee instability. Self-reported knee instability was operationalized by the sensation of an episode of buckling, shifting, or giving way of the knee in the previous 3 months, based on a questionnaire from Felson et al (1). Persons reporting knee instability were additionally asked for the number of episodes of instability in the previous 3 months, whether these episodes concerned the left, right, or both knees and if they had resulted in a fall; and the particular activity that induced an episode of instability. Self-reported knee instability was dichotomized as follows: no episodes of knee instability in the previous 3 months versus 1 or more episodes of knee instability in the previous 3 months.

Biomechanical factors. Muscle strength. Muscle strength was assessed for knee flexion and extension using an isokinetic dynamometer (EnKnee, Enraf-Nonius) (19). Quadriceps and hamstring strength were measured isokinetically at 60°/second. Patients performed 3 maximal test repetitions to measure strength of the quadriceps and hamstrings for each knee. Mean muscle strength per leg was calculated to obtain a measure of overall leg muscle strength (in Nm). Subsequently, mean muscle strength was divided by patient's weight to control for the correlation between muscle strength and weight. This normalized measure (in Nm/kg) was used for the analyses. Excellent intrarater reliability (intraclass correlation coefficient [ICC] 0.93) has been reported for this measure in knee OA patients (28).

Proprioceptive accuracy. Proprioceptive accuracy (motion sense) was assessed using a knee joint motion detection task (19). In a sitting position (semi-reclined), both knees were moved to a starting position of 30° flexion. From this position, computer-controlled constant angular motion of one knee was initiated at a velocity of 0.3°/second in the extension direction. The subject pushed a button after definite detection of knee joint motion: the right button after detecting motion of the right knee, the left button after detecting motion of the left knee. The ordering of the leg being tested was random. Visual and auditory stimuli, mechanical vibrations, cutaneous tension, and pressure cues were minimized. The threshold for detection of knee joint motion was assessed by the difference of knee joint position, in degrees, between the actual onset of motion and the subject's detection of knee motion. The mean of 3 measurements was calculated for each knee. Intra- and interrater reliability (ICC 0.91) in knee OA patients has been found to be excellent (29).

Laxity. Varus-valgus laxity was operationalized as the movement in the frontal plane after varus and valgus load (14;30). In a sitting position, the thigh and lower leg were fixed at 5 places to prevent for medial or lateral movement of the thigh and lower leg and for hip rotation. With a fixed knee flexion of 20°, a load of 1.12 kg was applied to the lower leg both medially and laterally, resulting in varus or valgus movement across the transverse axis of the knee joint. This weight was attached to the free-moving arm of the apparatus by a cord. The cord was attached 0.68 meters from the pivot of the arm, resulting in a net moment on the knee of 7.7 Nm. The total amount of movement (in varus and valgus directions) was assessed in degrees. Three consecutive measurements were made, and right/left order was alternated between subjects. The mean of 3 measurements was calculated for each knee. Intra- and interrater reliability (ICC) for this measurement in healthy persons is 0.80 and 0.88, respectively (31).

Possible confounders. Other factors that have been suggested to be associated with self-reported knee instability, i.e., body mass index (BMI), radiographic severity of knee OA (ROA), and malalignment (1-4) were assessed. BMI was calculated as body mass in kilograms divided by height in meters squared. ROA was assessed by weightbearing anteroposterior radiographs of the knee joints following the protocol from Buckland-Wright et al (32;33). Radiographic features were scored according to the paired reading procedure by 2 independent observers. One observer was a bone and joint radiologist. The second observer was an experienced epidemiologist, trained by 2 musculoskeletal radiologists in reading knee and hip radiography. Knee radiographs were read in a paired fashion, blinded to sequence. The 2 readers separately evaluated the Kellgren & Lawrence grade (K&L) of each knee as well as individual radiographic features of each compartment of the knee (34-36). Both readers were not aware of the clinical characteristics of the patient. Disagreements on individual radiographic features and K&L grade between both readers were adjudicated. Malalignment of the knee in the frontal plane was assessed during physical examination with a goniometer in a standing position with knees extended. The frontal plane angle of the knee (hip-knee-ankle angle) in varus or valgus direction was measured in degrees from neutral alignment. Use of stabilizing walking devices like knee braces, canes, or crutches was also included as a possible confounder.

Furthermore, although knee pain presumably is a consequence of episodes of knee instability rather than a cause, we also included severity of knee pain as a possible confounder. Knee pain in the previous week was assessed by a numeric rating scale that ranges from 0 (no pain) to 10 (worst imaginable pain). Additionally, use of pain medication (including nonsteroidal anti-inflammatory drugs) for the knee was included as a possible confounder. Finally, general patient characteristics (sex, age, and duration of knee symptoms) were obtained.

Index knee. Muscle strength, proprioceptive accuracy, laxity, ROA, and malalignment are knee-specific variables. For these variables, measurements of 1 particular knee (index knee) per person were analyzed. For persons reporting knee instability in 1 knee, measurements of this particular knee were used for statistical analysis. For persons reporting knee instability in both knees or persons reporting no knee instability at all, measurements of a randomly chosen knee were used.

Statistical analysis

Descriptive statistics for biomechanical factors and possible confounders were calculated for the total group, as well as for persons reporting knee instability and persons reporting no knee instability, separately. Differences on these variables between the 2 groups were analyzed using Student's *t*-test or chi-square test. Furthermore, descriptives for variables on self-reported knee instability were calculated.

To address the aim of the study, logistic regression analyses were performed to analyze the associations between biomechanical factors (muscle strength, proprioceptive accuracy, and laxity) and self-reported knee instability. Independent variables were the biomechanical factors. Dichotomous dependent variable was self-reported knee instability (i.e., presence versus absence of self-reported knee instability). First, univariable logistic regression analyses were performed to assess the univariable association of muscle strength, proprioceptive accuracy and laxity to self-reported knee instability (crude models). Second, interaction effects between muscle strength and each of the other biomechanical factors (muscle strength x proprioceptive accuracy and muscle strength x laxity) and their association with self-reported knee instability were calculated. For this purpose, data on muscle strength, proprioceptive accuracy, and laxity were centered around the mean to analyze interaction effects properly, as recommended by Aiken and West (37). Third, for the associations between one biomechanical factor (muscle strength, proprioceptive accuracy, or laxity) and self-reported knee instability, a confounding role of the other 2 biomechanical factors were analyzed. A 10% change in the crude regression coefficient of the first determinant, after adjustment for a second variable, was indicative for relevant confounding (38). Fourth, a confounding role of general patient characteristics (sex, age, duration of knee symptoms) and variables that are possibly associated with self-reported instability (BMI, ROA, malalignment, knee pain, use of pain medication, and use of walking devices) were determined, based again on a 10% difference between crude and adjusted regression coefficient.

Prior to these analyses, interaction effects between sex and each of the biomechanical factors and their association with self-reported knee instability were calculated to determine whether stratification for sex was needed. Because no interaction effects were found (data not shown), men and women could be analyzed together.

Statistical significance was accepted at *P* values less than 0.05 and 95% confidence intervals (95% CIs) for odds ratios (ORs) not including 1. All analyses were performed using SPSS software, version 15.0.

Results

Descriptives. Patient characteristics (*n*=283) are shown in Table 1. Almost two-thirds (64%) of the study group were women and the mean ± SD age was 61.6 ± 7.4 years. No significant differences between persons reporting knee instability and persons reporting no knee instability were found on any of the patient characteristics, except for muscle strength (*P*<0.001) and knee pain (*P*<0.05).

Table 2 shows that 67% (*n*=191) of the knee OA patients reported a sensation of buckling, shifting or giving way in the previous 3 months. Knee instability was mostly reported unilaterally (75% of persons reporting knee instability). Ten percent of persons reporting knee instability had had a fall accident due to an episode of knee instability in the previous 3 months. Most episodes of knee instability occurred during walking (59% of persons reporting knee instability).

Table 1. Characteristics of the total study group*

	Total group (*n*=283)	Persons reporting knee instability (*n*=191)	Persons reporting no knee instability (*n*=92)
Sex, % female	64%	66%	61%
Age, years	61.6 ± 7.4	62.1 ± 7.3	60.6 ± 7.6
Duration of knee complaints, years	10.6 ± 9.6	11.4 ± 9.9	9.1 ± 8.9
Muscle strength, Nm/kg	0.87 ± 0.42	0.80 ± 0.41†	1.02 ± 0.39†
Proprioceptive accuracy, degrees	3.1 ± 2.5	3.2 ± 2.6	2.9 ± 2.2
Laxity, degrees	7.3 ± 4.0	7.2 ± 3.9	7.5 ± 4.1
Body mass index, kg/m^2	29.2 ± 5.5	29.5 ± 5.7	28.6 ± 5.0
Radiographic OA, % K/L score ≥2	67%	67%	66%
Malalignment, degrees from neutral alignment in varus or valgus direction	5.3 ± 4.1	5.5 ± 4.4	4.9 ± 3.2
Severity of knee pain severity (range 0-10)	5.0 ± 2.2	5.2 ± 2.2‡	4.6 ± 2.2‡
Use of walking devices for knee, % yes	16%	19%	11%
Use of pain medication for knee, % yes	42%	45%	35%

OA=osteoarthritis; K/L=Kellgren/Lawrence; * values are the mean ± SD unless otherwise indicated; † significant difference between subgroups (P<0.001); ‡ significant difference between subgroups (P<0.05).

Associations between biomechanical factors and self-reported knee instability. Table 3 shows crude and adjusted ORs of the associations between muscle strength, proprioceptive accuracy, and laxity, and self-reported knee instability. Muscle strength was significantly associated with self-reported knee instability (crude OR 0.28, 95% CI 0.15, 0.52), i.e., higher muscle strength is significantly associated with the absence of self-reported knee instability. Proprioceptive accuracy and laxity did not confound this relationship. After the addition of one possible confounder at a time (sex, age, duration of knee symptoms, BMI, ROA, malalignment, knee pain, use of pain medication, and use of walking devices) to the crude model, sex was found to be the only relevant confounder (i.e., more than 10% change in crude regression coefficient for muscle strength). In the model adjusted for sex, muscle strength was even more strongly associated with self-reported knee instability (adjusted OR 0.18, 95% CI 0.08, 0.40). Muscle strength was still strongly associated with self-reported knee instability after adjustment for all possible confounders (adjusted OR 0.15, 95% CI 0.05, 0.40). Proprioceptive accuracy (crude OR 1.05; 95% CI 0.95, 1.17) and laxity (crude OR 0.98, 95% CI 0.92, 1.05) were not associated with self-reported knee instability. ORs for proprioceptive accuracy and laxity hardly changed after adjustment for the other 2 biomechanical factors. Furthermore, no relevant confounders were found that changed crude regression coefficients of proprioceptive accuracy or laxity.

Table 2. Self-reported knee instability in knee OA patients

	No. (%)
Sensation of episode of buckling, shifting or giving way of the knee in previous 3 months:	
no	92 (33%)
yes	191 (67%)
total	283 (100%)
Number of episodes of buckling, shifting or giving way of the knee in previous 3 months:	
1-2 episodes	90 (47%)
3-5 episodes	68 (36%)
>5 episodes	33 (17%)
total	191 (100%)
Episode of buckling, shifting or giving way of the knee in:	
one knee	144 (75%)
both knees	45 (24%)
unknown	2 (1%)
total	191 (100%)
Fall due to episode of buckling, shifting or giving way of the knee:	
yes	18 (10%)
no	173 (90%)
total	191 (100%)
Activity reported at time of episode of buckling, shifting or giving way of the knee:	
walking	113 (59%)
rising from chair	60 (31%)
ascending stairs	58 (30%)
twisting or turning	55 (29%)
descending stairs	41 (21%)
sitting down in chair	6 (3%)
other activity	35 (18%)

* Multiple activities for each person are possible.

Table 3. Associations between biomechanical factors and self-reported knee instability*

	Crude OR	95% CI	*P*	Adjusted OR†	95% CI	*P*	Adjusted OR‡	95% CI	*P*
Muscle strength	0.28	0.15, 0.52	<0.001	0.24	0.12, 0.47	<0.001	0.18	0.08, 0.40	<0.001
Proprioceptive accuracy	1.05	0.95, 1.17	0.36	1.01	0.90, 1.12	0.92			
Laxity	0.98	0.92, 1.05	0.60	0.96	0.90, 1.02	0.19			

OR=odds ratio; 95% CI=95% confidence interval; * an odds ratio (OR) between 0 and 1 indicates a lower risk for self-reported knee instability; an OR > 1 indicates a higher risk for self-reported knee instability; † adjusted for the other 2 biomechanical factors; ‡ adjusted for relevant confounding.

Table 4. Interaction terms between muscle strength and proprioceptive accuracy (model 1) and between muscle strength and laxity (model 2) for the association with self-reported knee instability

	OR	95% CI	*P*
Model 1			
Muscle strength	0.28	0.15, 0.54	<0.001
Proprioceptive accuracy	1.01	0.91, 1.13	0.84
Muscle strength x proprioceptive accuracy	0.99	0.75, 1.31	0.95
Model 2			
Muscle strength	0.23	0.12, 0.46	<0.001
Laxity	0.96	0.91, 1.02	0.17
Muscle strength x laxity	1.01	0.87, 1.18	0.88

OR=odds ratio; 95% CI=95% confidence interval.

Table 4 shows that no effect modification could be demonstrated between muscle strength and proprioceptive accuracy (model 1), or between muscle strength and laxity (model 2), as indicated by nonsignificant interaction terms (P=0.95 and P=0.88, respectively).

Self-reported knee instability was additionally subdivided into 3 instead of 2 categories (0= no episode of knee instability in the previous 3 months; 1= 1-2 episodes of knee instability in the previous 3 months; 2= more than 2 episodes of knee instability in the previous 3 months) and analyzed for its association with biomechanical factors. The ordinal regression analyses confirmed the results reported above (data not shown).

Discussion

In the present large cohort study, we focused on the associations between muscle strength, proprioceptive accuracy, laxity, and self-reported knee instability in knee OA patients. Lower muscle strength was significantly associated with the presence of self-reported knee instability, even after adjustments for factors such as BMI, ROA, malalignment, and knee pain. Impaired proprioceptive accuracy and high laxity were not associated with self-reported knee instability.

Muscles around the knee are presumed to be major stabilizers of the knee joint (20;22) and are considered to play a crucial role in knee stability in patients with knee OA (2;8;14;17;19). The presence of episodes of knee buckling has been found to be related to weaker lower limb muscle strength in a large study cohort (but not exclusively knee OA patients) (1). To our knowledge, our study is the first in which an association between muscle strength and self-reported knee instability in knee OA patients has been demonstrated. Schmitt and Rudolph found no difference in muscle strength between 10 knee OA patients with knee instability and 10 knee OA patients without knee instability (13). In another small study by Schmitt et al, in 52 knee OA patients, again there was no association found between muscle strength and knee instability (4). These 2 studies were likely experiencing a lack of power, which could explain the nonstatistical differences.

Conflicting evidence has been reported on the role of muscles in disease progression of knee OA. Some longitudinal studies have demonstrated a role of lower muscle strength in the onset (16;22;39) and progression (40;41) of radiographic knee OA, while one other longitudinal study showed that in malaligned or lax knees, progression of radiographic knee OA was associated with higher muscle strength (42). We showed an association between lower muscle strength and self-reported knee instability. Since recurrent episodes of knee instability are suggested to cause excessive shear forces in the knee joint (43;44), thereby possibly leading to further progression of knee OA (7;13), our study results are consistent with the hypothesis of muscle weakness causing knee OA onset and progression.

Both proprioceptive accuracy (motion sense) and frontal plane (varus-valgus) laxity were not associated with self-reported knee instability in our study. Two explanations can be offered for these nonsignificant findings. The first possible explanation is the operationalization of proprioceptive accuracy and laxity that we used in the present study. Proprioceptive accuracy was measured in our study by a passive motion sense test, whereas the study of Collins et al (25), in which proprioceptive accuracy was significantly associated with self-reported knee instability, used an active position sense test. Because motion sense and position sense poorly correlate to each other (18), the difference in measurement of proprioceptive accuracy between the study by Collins et al and our study may have led to conflicting results. Furthermore, knee movements during our motion sense test were directed towards knee extension, while Collins et al positioned knees in the direction of flexion. Episodes of knee instability might predominantly occur during knee flexion. This could also be an explanation of the nonstatistical association of proprioceptive accuracy in knee instability in our study. Frontal plane (varus-valgus) laxity has never been found to be associated with self-reported knee instability (3;4;6;13). Because episodes of knee instability might mainly represent movements in the sagittal plane, sagittal plane laxity (17;45;46) could be more strongly related to self-reported knee instability, compared to frontal plane laxity. Unfortunately, no study has focused on the relationship between sagittal laxity and knee instability. Since the sensation of knee instability occurs at a time of weight bearing, proprioceptive accuracy and laxity may also need to be measured in a weightbearing position, instead of in a sitting position as in our study, to find an association with self-reported knee instability. The second possible explanation for the nonsignificant findings of proprioceptive accuracy and laxity could be a discrepancy between biomechanical knee instability (i.e., knee instability due to biomechanical impairments) and self-reported knee instability (i.e., knee instability that is perceived by a patient during dynamic and functional activities). Biomechanical and self-reported instability could represent 2 independent components of knee instability, implicating that both need to be assessed in clinical practice. Some studies have attempted to measure knee stability under dynamic conditions by assessing two-dimensional (47;48) or three-dimensional (49) movements of the knee joint during walking, but no studies have yet focused on the relationship between dynamic knee instability and self-reported knee instability.

We were not able to confirm our hypothesis of muscle strength being able to compensate for impaired proprioceptive accuracy or high laxity, in order to maintain knee stability. Effect modification between muscle strength and proprioceptive accuracy and between muscle strength and laxity in relationship to self-reported instability was absent, as shown by nonsignificant interaction terms. This lack of evidence for interactions between biomechanical factors may be caused by the lack of any association between proprioceptive accuracy and laxity, and self-reported instability. Interactions between muscle strength and proprioceptive accuracy (19;22) and between muscle strength and laxity (8;14;17) have frequently been proposed in knee OA literature, when concerning knee stability, but have never actually been demonstrated. Studies by our own study group (14;19) demonstrated that in persons with impaired proprioceptive accuracy or with high varus-valgus laxity, a decline in muscle strength resulted in a stronger detoriation in activity limitations, compared to persons with adequate proprioceptive accuracy or low laxity. These results suggest that muscle strength is required for successful joint stabilization and maintenance of physical functioning. A large body of literature exists demonstrating altered walking patterns (e.g., higher quadriceps and hamstrings activation and less knee excursion) in knee OA patients (3;5-13), presumably as a strategy to stabilize the knee joint despite impairments in proprioceptive accuracy and laxity. These altered walking patterns further suggest a key role of the muscles in maintaining knee stability.

In our study, a substantial proportion (67%) of the knee OA population reported knee instability, which is similar to earlier studies (2-6). A large number of knee OA patients may therefore be in need of treatment specifically aiming to improve knee stability. Knee instability is thought to be highly treatable (2), although no studies have yet demonstrated an effective treatment. Because our study had a cross-sectional design, no causal conclusions are warranted. Nevertheless, the present study supports the important role of lower limb muscles in maintaining knee stability. We hypothesize that an exercise program consisting of neuromuscular exercises might be beneficial in improving knee stability. Since both ours and one other study (1) showed that most episodes of buckling, shifting, or giving way of the knee occurred during walking, treatment may need to specifically focus on stabilization strategies during walking. Promising results on the effectiveness of an exercise program consisting of neuromuscular exercises combined with functional exercises (particularly walking) in knee OA patients have been reported in a nonrandomized study (50) and a case report (51). Other interventions, such as taping, braces, or treatment of effusion might also prove effective. Randomized controlled trials are needed to demonstrate the effectiveness of interventions that specifically aim to improve knee stability in knee OA patients. Approximately 1 out of 10 persons in our study with self-reported knee instability had had a fall in the previous 3 months after an episode of buckling, shifting, or giving way of the knee (Table 2). This is consistent with the literature (1). Interventions focusing on knee stability may therefore also have beneficial effects on fall prevention.

The cross-sectional design of our study is a limitation. We showed that lower muscle strength is associated with a higher presence of self-reported knee instability. It remains unclear whether lower muscle strength is a cause of knee instability or vice versa, or that other factors affect both muscle strength and knee instability, for example knee pain. The role of knee pain in self-reported knee instability is not clear. Some small studies revealed that knee pain can affect neuromuscular function (e.g., quadriceps muscle coordination (52), motor unit recruitment and force direction (53)). Knee pain has also been found to be associated with proprioceptive accuracy (18). Our study demonstrated that knee pain does not play a role in the association between biomechanical impairments and self-reported instability. Future longitudinal studies need to focus on possible causes of self-reported knee instability.

To conclude, lower muscle strength is strongly associated with self-reported knee instability in knee OA patients, while impairments in proprioceptive accuracy and laxity are not. A compensatory role of muscle strength for impaired proprioceptive accuracy or high laxity, in order to stabilize the knee could not be demonstrated.

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