Falls Associated with Muscle Strength in Patients with Knee Osteoarthritis and Self-reported Knee Instability

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ABSTRACT. Objective. We aimed to evaluate the associations between knee muscle strength (MS) and falls, controlling for knee joint proprioception, varus-valgus knee joint laxity, and knee pain, among patients with knee osteoarthritis (OA) reporting knee instability.

Methods. A sample of 301 subjects (203 women, 98 men, 35–82 yrs) with established knee OA and self-reported knee instability was studied. The occurrence of at least 1 fall in the previous 3 months was assessed by questionnaire. Maximum knee extension and flexion strength were measured isokinetically. Additionally, proprioception, varus-valgus laxity, and pain were assessed. Student t tests were used to assess differences between subgroups. The association of muscle strength and falls was calculated using univariate and multivariate logistic regression analysis.

Results. Over 10% of the subjects (31 out of 301) reported a fall in the previous 3 months. High knee extension muscle strength (crude OR 0.3, 95% CI 0.1–0.8, p = 0.022) and high knee flexion muscle strength (crude OR 0.2, 95% CI 0.0–1.0, p = 0.048) were associated with a lower risk of falls. Proprioception and laxity did not confound this relationship. After adjusting for pain, extensor strength had an adjusted OR of 0.5 (95% CI 0.2–1.4, p = 0.212) for falls and flexor strength had an adjusted OR of 0.4 (95% CI 0.1–2.3, p = 0.312).

Conclusion. High knee extension and flexion muscle strength decreased the risk of falls in patients with knee OA and self-reported knee instability. After considering the effect of pain, there was insufficient statistical power to detect an association between muscle strength and falls, which might be because of the low number of subjects who fell (n = 31).

Keyword Indexing Terms:
ACCIDENTAL FALLS
MUSCLE STRENGTH
KNEE JOINT
PROPRIOCEPTION
OSTEOARTHRITIS
JOINT LAXITY

Falls are a leading cause of injuries, activity limitations, and death among older adults. In patients with knee osteoarthritis (OA), the 1-year fall incidence has been reported to be about 30% higher than in healthy older adults of the same age. Despite the elevated incidence of falls in patients with knee OA, the underlying mechanisms of falls in patients with knee OA are poorly understood.

Self-reported knee instability is the perception of slipping or giving way of the knee. About 60–80% of the patients with knee OA report knee joint instability. Muscle weakness is associated with knee joint instability and is a known risk factor for falls in the general older population and arthritis population. However, whether muscle weakness is (strongly) associated with falls in patients with knee OA is still unknown, yet relevant for their fall risk and treatment. It has been reported that patients with knee OA commonly generate lower maximum forces in knee flexors and extensors, the knee stabilizers, than their healthy peers. In knee OA, muscle weakness possibly arises because of neuromuscular inhibition by knee pain and muscle atrophy by avoidance of daily activities.
weakness might contribute to the high incidence of falls in patients with knee OA with self-reported knee instability8,14. Therefore, muscle weakness is hypothesized to be associated with falls in patients with knee OA and self-reported knee instability. Other factors may confound the relationship between muscle weakness and falling. Decreased proprioceptive accuracy, deficient or delayed detection of motion or position of the joint in knee OA may hamper faster and adequate responses to perturbations of knee motion25,26. High varus-valgus knee joint laxity might delay neuromuscular responses because relatively larger joint excursions are required to activate high threshold mechanoreceptors27. Finally, higher knee pain levels, a dominant symptom in knee OA2 and linked to knee instability8, might increase the risk of falls within this subgroup. Higher knee pain levels were reported in patients with lower-limb arthritis reporting falls than in patients with arthritis without falls16. This may be because of detrimental effects of pain on muscle strength28, but also on motor responses responsible for counteracting perturbations to avoid a fall25,26.

Knowledge of whether muscle strength is an important factor in the high numbers of falls reported in the knee OA population is essential for developing and prescribing adequate treatment. Therefore, the aim of our study was to evaluate the association between knee muscle strength and falls among patients with knee OA reporting knee instability, controlled for knee joint proprioception, varus-valgus knee joint laxity, and knee pain.

MATERIALS AND METHODS

Study population. A total of 301 patients with self-reported knee instability from the Amsterdam Osteoarthritis (AMS-OA) cohort, an open clinical population, were included in our study29. Knee instability was defined as the subjective perception of giving way of the knee. Subjects also had unilateral or bilateral knee OA according to the American College of Rheumatology (ACR). The AMS-OA is a cohort of patients with OA of the knee and/or hip according to the ACR criteria29,30 who have been referred to an outpatient rehabilitation center (Reade, Centre for Rehabilitation and Rheumatology, Amsterdam, the Netherlands). Patients were assessed by rheumatologists, radiologists, and rehabilitation physicians. Exclusion criteria were total knee replacement, hip OA, rheumatoid arthritis, or any other form of inflammatory arthritis (i.e., crystal arthropathy or septic arthritis). Demographic, clinical, radiographic, biomechanical, and psychosocial factors related to OA were assessed. All patients provided written informed consent according to the Declaration of Helsinki. The study was approved by the Slotervaart Hospital/Reade Institutional Review Board.

Outcome variable. Self-reported falls were assessed by a questionnaire at a dichotomous level according to Felson, et al8. Patients reported whether they had experienced at least 1 fall attributable to knee instability in the 3 months prior to their visit to the rehabilitation center. A fall was defined as an event in which a person unintentionally comes to rest on the ground or other lower levels31.

Independent variables. To measure muscle strength, maximum knee flexion (hamstring group) and extension strength (quadriceps group) were measured using an isokinetic dynamometer (EnKnee, Enraf-Nonius) for each leg in 3 test repetitions at 60°/s25. We calculated mean (over both legs) muscle strength (in Nm) for knee flexion and extension, and normalized this to body mass (in Nm/kg). Excellent intrarater reliability (ICC 0.93) has been reported for the assessment of muscle strength using an isokinetic dynamometer33. Proprioceptive accuracy of motion sense was assessed using a knee joint motion detection task. In a sitting position, both knees were moved to a starting position of 30° flexion. From this position, computer-controlled constant angular motion of a single knee was started at a velocity of 0.3/°s in the extension direction32. The patient pushed either a left or right button when sensing knee joint motion of the left or right knee, respectively. Each knee was tested 3 times in a randomized order. 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. We calculated the average value for the 3 measurements for each knee and the total average score including both legs. The average score of proprioception of the left and right knee was used in the statistical analysis. Intra- and interrater reliability for the assessment of knee proprioception using the test procedure described above (ICC 0.91) in patients with knee OA has been found to be excellent34.

Varus-valgus laxity of the knee was operationalized as the movement in the frontal plane after applying a load to the lower leg35,36. In a sitting position, the thigh and lower leg were fixed to the arms of the measurement device at 5 places. The thigh was fixed to the fixed arm of the device to prevent movement. With a fixed knee flexion of 20°, moments of 7.7 Nm in varus and valgus directions were applied by means of a load of 1.12 kg attached to the free-moving arm by a cord at 0.68 m from the pivot. The patients were instructed to relax upper leg muscles during the performance of the test. The total amounts of movement in varus and valgus directions (in degrees) were summed. Three consecutive measurements were made, and right/left order was alternated between subjects. The mean of the 3 measurements for each knee and the mean score for both legs was calculated. The average score of knee joint laxity of the left and right knee was used in the statistical analysis. Intra- and interrater reliability (ICC) for this measurement in healthy adults is greater than 0.80 and 0.88, respectively37.

Knee pain was assessed using a numerical rating scale (NRS) that ranged from 0 (no pain) to 10 (worst imaginable pain)38. The NRS has been shown to be a reliable and valid tool to measure pain levels, and is widely used in OA research39.

Other measures. Age, sex, body mass index (BMI), and Kellgren-Lawrence score (KL score) were obtained. Age and sex were assessed by a questionnaire. Body mass and body height were measured to calculate BMI. The KL score is a radiological assessment of the severity of knee OA ranging from 0 (no radiographic features visible) to 4 (radiographic features: joint narrowing, osteophyte formation, cysts, sclerosis, and attrition are visible). A KL score of 2 was considered radiographic knee OA40.

Statistical analysis. Descriptive statistics were used to characterize the total study population, those who fell, and those who did not fall. Normality checks (Kolmogorov-Smirnov tests, skewness, kurtosis, and histograms) were performed for all continuous variables. We performed Student t tests and chi-square tests to test for differences between those who fell, and those who did not fall.

To address the aim of the study, logistic regressions analyses were performed to analyze the associations between muscle strength and falls. The dichotomous dependent variable was falls (i.e., absence vs the presence of a self-reported fall). The independent variable was knee muscle strength (either flexion or extension strength).

First, univariate logistic regression analyses were performed to assess the univariate association of muscle strength to fall incidents (crude models). Second, multivariate logistic regressions were performed to test the association between muscle strength and falls for confounding and interaction by including proprioception, laxity, and knee pain stepwise to the regression analyses. When proprioception, laxity, or knee pain changed the crude regression coefficient of muscle strength by more than 10%, these variables were considered to be a confounder41. For the analysis with interaction terms, the independent variables of knee muscle strength, knee proprioception, knee joint laxity, and knee pain were centered on the mean because
multicollinearity decreases when variables are centered\(^4\). Finally, a
confounding role of general patient characteristics (age, sex, and KL score)
was determined, based again on a 10% difference between the crude and
adjusted regression coefficient.

Statistical significance was accepted for p values less than 0.05 and 95%
CI for OR not crossing 1. All analyses were performed using SPSS software,
version 18.0 (SPSS).

RESULTS

**Differences in characteristics between those who fell and those who did not fall.** Patient characteristics of the total study
group and separately for those who fell and those who did not fall are presented in Table 1. Out of 301 patients, 31
patients with knee OA with knee instability (10%) reported at least 1 fall incident in the previous 3 months. In those who
reported falls, significantly lower extension strength (mean 0.81 Nm/kg, SD 0.5) was measured than in those not
reporting falls [mean 1.0 Nm/kg, SD 0.5, \( t(283) = 2.336, p = 0.017 \)], and significantly lower flexion strength (mean 0.53
Nm/kg, SD 0.3) compared with those not reporting falls [mean 0.68 Nm/kg, SD 0.3, \( t(283) = 20.14, p = 0.041 \)]. Fallers
reported higher pain levels (mean 6.13, SD 2.4) than non-fallers [mean 4.1, SD 2.7, \( t(297) = -4.076, p < 0.001 \)]. Those reporting falls showed no significant differences in
proprioception (mean 3.1\(^o\), SD 2.0) and joint laxity (mean 8.0\(^o\), SD 3.4) compared with the others [mean 3.1\(^o\), SD 2.0,
\( t(296) = -0.601, p = 0.830 \), and mean 7.3\(^o\), SD 3.5, \( t(272) = -0.987, p = 0.214 \), respectively].

**Associations between muscle strength and falls.** In Table 2, it is shown that knee extension (crude OR 0.3, 95% CI
0.1–0.8, \( p = 0.022 \)) as well as knee flexion strength (crude OR 0.2, 95% CI 0.0–1.0, \( p = 0.048 \)) were significantly
associated with falls in patients with self-reported knee instability (i.e., higher muscle strength is significantly associated
with the absence of self-reported incidental falls). Proprioceptive accuracy did not confound this association, and
neither did knee joint laxity. Knee pain did affect the association between muscle strength and falls: extension strength
(adjusted OR 0.5, 95% CI 0.2–1.4, \( p = 0.212 \)) and flexion strength (adjusted OR 0.4, 95% CI 0.1–2.3, \( p = 0.312 \)). No
significant interaction effects were found (data not shown). After including sex, age, and the KL score, stepwise, it was found
that these variables did not confound the association between muscle strength and falls (data not shown).

DISCUSSION

In our present study, we focused on the associations between
muscle strength and falls, and controlled for potential
confounding factors (knee joint proprioception, knee joint
varus-valgus laxity, and knee pain) in a group of established
patients with knee OA reporting knee instability. It was
shown that high knee flexor and extensor strength were
associated with a lower odds of falling. Proprioception and
joint laxity did not confound this relationship. Knee pain
might be associated with falls when entered in the model with
muscle strength (OR 1.3, \( p = 0.017 \)) and might confound the
association between muscle strength and falls. However,
there was insufficient statistical power to detect the association
between muscle strength and falls once considering the
effect of pain. The results of our study indicate that upper leg
muscle strength is an important factor with respect to
incidental falls in patients with knee OA with self-reported
knee instability.

In the general older population, upper leg muscle
weakness is an important risk factor for falls\(^4,15\). Muscle
weakness is a characteristic of patients with knee OA and is
more severe in patients with knee OA compared with their

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<th>Table 1. Characteristics of study group.</th>
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<td>Characteristics</td>
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<tr>
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<td>Laxity, °, (SD)</td>
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<td>Knee pain severity, 0–10, (SD)</td>
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* Total no. participants for which data are available for each variable (no. those reporting falls for which data are
available for each variable). Significant numbers are in bold face. BMI: body mass index; OA: osteoarthritis; KL:
Kellgren and Lawrence.
The suitability of assessing dynamic gait stability measures with respect to falls in patients with knee OA needs to be further explored.

Our study has several limitations. First, the study population presented consisted of only patients with knee OA with self-reported knee instability. No information on fall incidents was available for patients with knee OA without self-reported knee instability. Therefore, our study focused on fall incidents in the subgroup of patients with knee OA reporting knee instability. This subgroup, however, concerns a large part of the total knee OA population, ranging from 60–80\%9,10,11,12,13. Second, falls were reported, retrospectively, over the last 3 months only, and whether these reported falls actually occurred and whether all falls were reported is unknown. Third, no information was available on the use of pain medication that is a known risk factor on falls15. Fourth, it is unclear in which manner knee muscle strength and pain increase the risk of falls in patients with knee OA is unknown. It can be speculated that the avoidance of pain, by decreasing force on the affected knee, may alter gait and lead toward a pattern more prone to falls50. Moreover, the presence of pain might cause muscle weakness through pain-related muscle inhibition24 that in turn may limit the ability to regain balance after a perturbation43,44. Although it is unclear how manner knee muscle strength and pain increase the risk of falls in patients with knee OA and self-reported knee instability, both are important underlying factors in falls.

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the study design was cross-sectional and hence causality cannot be inferred. Finally, not all patients’ data were available for all measurements of muscle strength, proprioception, or laxity (Table 1, last column) because in various cases, it was impossible to perform all measurements.

High knee extension and flexion muscle strength are associated with lower odds of fall events in patients with knee OA and self-reported knee instability. However, there was insufficient statistical power to detect the association between muscle strength and falls once considering the strong influence of knee pain on this association. Knee pain should be considered as an independent variable in the risk of falls in future research.

REFERENCES
34. Hurkmans EJ, van der Esch M, Ostelo RW, Knol D, Dekker J, Steultjes MP. Reproducibility of the measurement of knee joint...


