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Severity of Coexisting Patellofemoral Disease is Associated with Increased Impairments and Functional Limitations in Patients with Knee Osteoarthritis

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Abstract

Objective—To evaluate the association between severity of coexisting patellofemoral (PF) disease with lower limb impairments and functional limitations in patients with tibiofemoral (TF) osteoarthritis (OA).

Methods—Radiographic views of the TF and PF compartments, knee extension strength and knee range of motion were obtained for 167 patients with knee OA. Additionally, knee-specific symptoms and functional limitations were assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Activities of Daily Living Scale (ADLS).

Results—“Moderate/Severe PFOA” was associated with lower knee extension strength (1.4±0.5 Nm/BW) compared to “No PFOA” (1.8±0.5 Nm/BW). Additionally, total knee range of motion was significantly lower for patients with “Moderate/Severe PFOA” (120.8°±14.4°) compared to “No PFOA” (133.5°±10.7°) and “Mild PFOA” (125.8°±13.0°). “Moderate/Severe PFOA” and “Mild PFOA” were also associated with less pain while standing (OR= 0.2; 95% CI: 0.1,0.7 and OR= 0.2; 95% CI: 0.1,0.6, respectively) on the WOMAC and “Moderate/Severe PFOA” was associated with greater difficulty with going downstairs (OR=2.9; 95% CI: 1.0,8.1) on the ADLS.

Conclusion—It appears that knees with more severe coexisting PF disease demonstrate features distinct from those observed in TFOA in isolation or in combination with mild PF disease. Treatment strategies targeting the PF joint may be warranted to mitigate the specific lower limb impairments and functional problems present in this patient population.

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Knee osteoarthritis (OA) is a prevalent medical condition in older adults and one of the leading causes of disability in the U.S.[1, 2] For the most part, epidemiological and clinical studies of knee OA have traditionally focused on the disease status of the tibiofemoral (TF) compartments and the patellofemoral (PF) joint has seldom been considered. However, findings from several population-based studies of older adults with history of knee pain suggest that PFOA in isolation or combined with TFOA is commonly observed in this patient population.[3, 4] Thus, inclusion of PF joint assessment along with the TF joint has been deemed essential in studies of symptomatic knee OA.[4–6] However, the potential clinical impact of coexisting PFOA along with TFOA in individuals with symptomatic disease has not been fully clarified.

An important theme arising from image-based studies of knee OA suggests that structural abnormalities related to PFOA are significantly associated with knee pain.[7–11] In a study of 819 older adults with knee pain, greater radiographic disease severity of PF compartment was independently associated with higher pain and greater functional deficits.[5] Additionally, an increase in severity of isolated PFOA has been associated with greater levels of pain, stiffness and functional limitations.[6] However this conclusion was reached based on the comparison of knees with isolated PF disease and those without radiographic signs of TFOA. Identifying the impact of coexisting PF disease severity along with TFOA may be more important as knees with structural changes in both the TF and PF compartments are commonly observed, are more likely to be painful, and are associated with greater loss of function.[3, 4, 9] To this end, Englund and Lomander[9] reported more symptoms, lower functional status, and worse knee-related quality of life for patients with coexisting PF and TFOA many years after meniscal resection. However, Englund and Lomander did not examine the degree to which PFOA severity may impact these findings. To date, the potential influence of coexisting PFOA severity along with TFOA has not been fully elucidated.

As the odds of symptomatic disease and disability seem to be influenced by the compartmental pattern and severity of knee OA,[12–16] clinical recognition of specific features of coexisting PF disease and its severity may have great implications for diagnosis and treatment of patients with knee OA. Therefore, the objective of this study was to evaluate the association between severity of coexisting PFOA with lower limb impairments and limitations with activities of daily living in patients with TFOA.

PATIENTS AND METHODS

A secondary analysis of baseline data for individuals participating in a randomized clinical trial of exercise therapy for knee OA was performed.[17] Individuals were included in the study if they met the 1986 American College of Rheumatology clinical criteria for knee OA[18] and had grade II or greater Kellgren and Lawrence (KL)[19] radiographic changes in the TF joint of at least one limb. Patients were further asked to identify their most painful knee as the right or the left knee. From a pool of 183 subjects included in the parent clinical trial, 167 subjects with full radiographic and clinical data for the most painful knee were eligible for this secondary analysis. Reasons for ineligibility included absence of TFOA in the most painful knee (n=5), incomplete radiographic data for the PF joint (n=3), or missing data for lower limb impairments, knee symptoms, or functional limitations (n=8). Ethical approval was obtained for all phases of the study from the University of Pittsburgh’s institutional review board.

RADIOGRAPHIC VIEWS AND SCORING

Radiographs of the painful knee in those with unilateral symptoms and the most painful knee in patients with bilateral involvement were analyzed. Three radiographic views of the index knee were obtained for each subject: 1) a semi-flexed, weight-bearing, anteroposterior view; 2) a lateral view; and 3) a skyline view. A single trained rheumatologist (C.V.O) scored all films. The KL scoring system was used to assign radiographic OA grades for each knee compartment based on the following criteria: Grade 0 = no osteophytes; Grade I = doubtful osteophytes (<1mm); Grade II = minimal osteophytes, possibly with joint space narrowing, cysts, and sclerosis; Grade III = moderate or definite osteophytes and or moderate joint space narrowing; and Grade IV= large osteophytes and/or severe joint space narrowing. TFOA was defined by a KL score of ≥II on the AP view. Subjects with TFOA were then stratified into three groups of “No PF OA” (KL score of ≤I), “Mild PFOA” (KL score of = II) or “Moderate/Severe PFOA” (KL score of ≥III) based on the severity of their PF disease assessed on the skyline and/or the lateral radiographic views. To determine whether reliable data could be obtained with respect to radiographic scoring of knee OA, KL scoring was repeated for a subset of 15 knees on two different days at least 7 days apart. Un-weighted kappa coefficients and exact percentage agreement were calculated. Intra-rater reliability scores were excellent for the medial and lateral TF compartments (kappa coefficient = 0.86; percent agreement = 93.3%) and the PF compartment (kappa coefficient = 0.80; percent agreement = 86.7%).

LOWER LIMB IMPAIRMENTS

The maximum voluntary isometric torque output for knee extension was measured using a Biodex System 3 dynamometer (Biodex Medical Systems, Inc. Shirley, NY). All tests were performed with the subject seated and the tested knee flexed to 60°. A minimum of 3 trials and maximum of 6 trials were performed. After 3 trials, when a trial had a maximum torque output less than the previous trial, the strength testing was concluded. The highest maximum torque output from all trials was recorded as the knee extension strength score. To allow for between subject comparisons, all maximum torque measurements were normalized to the subject’s body weight. Analysis of 40 subjects’ maximum voluntary isometric torque output on two different days indicated that this procedure yields reliable measurements. An intra-class correlation coefficient (ICC [2,k, where k=3]) of .97, with a 95% confidence interval of .94 to .98 was obtained for test-retest reliability of our testing procedures. In addition, knee flexion and extension range of motion were measured in degrees using standard goniometric procedures. Excellent intra-class correlation coefficients of between .84 to .93 have been reported for goniometric measurements of knee joint range of motion.[20, 21]

SELF-REPORTED SYMPTOMS AND FUNCTIONAL STATUS

The 24-item Western Ontario and McMaster Universities (WOMAC) OA Index and the 14-item Activities of Daily Living Scale (ADLS) of the Knee Outcome Survey were used to gather knee-specific information on symptoms and limitations during performance of functional tasks. The WOMAC is a valid and reliable disease-specific measure of pain, stiffness and physical function for individuals with knee OA.[22–25] Each item on the WOMAC has five response options (none, mild, moderate, severe, extreme) and yields a total subscale scores for pain (5 items, range 0–20), stiffness (2 items, range 0–8), function (17 items, range 0–68), and a total composite score (24 items, range 0–96). Higher scores on the WOMAC indicate increased severity of symptoms or functional limitations. The ADLS consists of 14 items that measure the full spectrum of symptoms and functional limitations during activities of daily living as a result of a variety of knee pathologies.[26] Each item on the ADLS has six response options (none, minimal, slight, moderate, severe, and extreme). The ADLS score is transformed to a 0 to 100 point scale with 100 indicating the absence of symptoms and functional limitations. ADLS has proven to be a reliable, valid, and responsive instrument for the assessment of functional limitations that result from disorders and impairments of the knee.[26, 27]

STATISTICAL ANALYSIS

Descriptive statistics were calculated and the normality of the distributions of all continuous variables was checked. Analysis of Variance (ANOVA) and Chi-square tests were used to determine group differences in demographics, radiographic knee OA severity, knee-specific impairments, as well as WOMAC and ADLS scores. Where appropriate, ANOVA tests were adjusted for gender, age (<60, 60–70, >70 years), BMI (<25, 25–30, >30 kg/m^2), and TFOA disease severity (KL = 2, 3, 4). The association between severity of PFOA and individual items on the WOMAC and ADLS scales were evaluated using multivariable adjusted logistic regression models. Individual items on the WOMAC, categorized as "normal/mild" or "moderate/severe/extreme" for pain, stiffness, or physical function limitations were the outcome variables for the logistic regression models. The individual items on the ADLS were dichotomized as "none/minimal/slight" or "moderate/severe/extreme" for symptoms and difficulty with the activities of daily living and were analyzed in a similar manner. The associations between severity of PF disease and the individual items on the WOMAC and the ADLS scales were expressed as adjusted odds ratios (OR) accounting for gender, age (<60, 60–70, >70 years), BMI (<25, 25–30, >30 kg/m^2), and TFOA disease severity (KL = 2, 3, 4) as covariates in the model. In addition, post-hoc analyses using adjusted logistic regression models were performed to evaluate the associations between knee-specific impairments and difficulty with specific items on the WOMAC and ADLS scales which were deemed to be problematic due to increases in PFOA severity. All statistical comparisons were two-tailed and differences were considered significant at a p-value of less than 0.05 using STATA statistical program (version 11.2, StataCorp, College Station, TX).

RESULTS

Patients with "Moderate/Severe PFOA" had significantly higher body weight (89.6±17.4 kg vs. 79.4±13.0 kg) and higher BMI (31.9±6.2 kg/m^2 vs. 28.1±4.2 kg/m^2) in comparison to those with "No PFOA" (Table 1). Patients with "Mild PFOA" also had a higher BMI (30.7±7.2 kg/m^2 vs. 28.1±4.2 kg/m^2) and were significantly older (65.6±9.1 and 60.5±8.1) compared to the "No PFOA" group. Additionally, those with "Moderate/Severe PFOA" were more likely to be female compared to patients with "Mild PFOA" (77.5% vs. 57.1%). The "No PFOA" group also had a higher proportion of patients with grade II TFOA (36.4%) as compared to patients in the "Mild PFOA" (7.9%) and "Moderate/Severe PFOA" groups (12.6%). Conversely, the "Moderate/Severe PFOA" group had a higher proportion of grade IV TFOA (43.7%) compared to the "No PFOA" group (18.2%).

Comparisons of the composite WOMAC and ADLS scores showed no statistically significant differences between the "No PFOA" group and the "Mild PFOA" or the "Moderate/Severe PFOA" groups (Table 2). "Moderate/Severe PFOA" was associated with lower knee extension strength (1.4±0.5 Nm/BW) compared to the "No PFOA" (1.8±0.5 Nm/BW). Total knee range of motion as well as knee flexion range of motion (Table 2) were also significantly lower for patients with "Moderate/Severe PFOA" (Total motion: 120.8°±14.4°and flexion motion: 126.8°±10.9°) compared to those with "No PFOA" (Total motion: 133.5°±10.7°and flexion motion: 136.9°±7.8°) and "Mild PFOA" (Total motion: 125.8°±13.0°and flexion motion: 130.8°±10.9°).

Across the individual WOMAC items (Table 3), logistic regression analyses revealed that more severe PF joint disease was independently associated with lower odds of reporting pain while standing for patients with "Mild PFOA" (OR = 0.2; 95% CI: 0.1,0.6) as well as those with "Moderate/Severe PFOA" (OR = 0.2; 95% CI: 0.1,0.7) when compared to patients with "No PFOA". In addition, "Mild PFOA" was associated with greater difficulty with taking off socks or stockings (OR = 4.3; 95% CI: 1.2,16.1) in comparison to "No PFOA". A post-hoc analysis further revealed that difficulty with taking off socks or stockings was also associated with lower knee flexion range of motion (OR = 0.95 per 1 degree unit; 95% CI: 0.92 to 0.99; P = 0.01) after adjusting for age, gender, BMI, and TFOA disease severity. However, difficulty with taking off socks or stockings was not associated with normalized quadriceps strength, total knee range of motion, or knee extension range of motion.

Finally, “Moderate/Severe PFOA” was independently associated with greater limitations with going downstairs (adjusted OR = 2.9; 95%: CI 1.0 to 8.1) on the ADLS scale (Table 4). Further post-hoc analyses revealed that greater difficulty with going down stairs on the ADLS scale was significantly associated with lower knee extension strength (OR = 0.41 per 1 Nm/kg unit; 95% CI: 0.16 to 0.99; $P < 0.05$) after adjusting for age, gender, BMI, and TFOA disease severity. However, knee flexion or extension range of motion or the total available knee range of motion was not associated with reports of difficulty with going down stairs on ADLS scale.

DISCUSSION

Coexisting PF and TF disease is a common radiographic pattern of knee OA observed in older adults with knee pain.[3, 4] In addition, symptomatic disease and reduced function are more likely to be found if radiographic OA changes are present in both the TF and PF compartments.[9] The findings from the current study suggest that the severity of coexisting PF disease may also be important. It appears that knees with coexisting “Moderate/Severe” PF disease demonstrate features distinctly different from those observed in TFOA without presence of PFOA. More specifically, “Moderate/Severe PFOA” seems to be associated with lower limb impairments of lower knee extension strength and limitations of knee range of motion.

Overall, although a trend towards clinically important differences in WOMAC[28] and ADLS[29] scores were noted in our cohort, these group differences did not reach statistical significant. This finding is most likely due to large within group variability and lack of statistical power of our study after adjusting for multiple confounders. However, as overlap in item content associated with the composite WOMAC and ADLS scores may have masked specific symptoms and functional limitation,[30] an individual item analysis was also performed. This analysis revealed that the severity of coexisting PF disease is associated with greater odds of having difficulty with going downstairs on the ADLS scale but not on the WOMAC. The lack of concordance between the two instruments may have been related to variability in patient responses due to differences in phraseology used in describing similar items and/or the difference in item response structure (i.e. 5 options for WOMAC vs. 6 options for ADLS). Alternatively, given that the proportion of patients reporting difficulty with going downstairs on both instruments was very similar (table 3 and 4), it could also be argued that our study might have been underpowered to detect differences for this item on the WOMAC.

The specific item analysis also revealed that greater severity of PF compartment disease is associated with lower odds of having pain while standing on the WOMAC pain subscale after adjusting for age, gender, BMI, and TF disease severity. This finding was unexpected and difficult to explain. However, it could be reasoned that the fully extended knee position during standing disengages the patella from the femur to unload sensitive PF compartment structures. Biomechanical studies support this notion as a reduction in PF joint contact pressures have been reported when the knee is fully extended compared to when the knee is in greater degrees of flexion during weightbearing tasks.[31–33]

Another unexpected finding from our specific item analysis was a greater odds of having difficulty with taking off socks or stockings for patients with “Mild PFOA” compared to those with No PFOA. Because high degrees of knee flexion range of motion are needed to perform this task, we hypothesized that limited knee joint mobility may explain the greater reports of difficulty. To explore this hypothesis, a post-hoc analysis of the association between knee flexion range of motion and reports of difficulty with taking off socks or stockings on the WOMAC was performed. The results of this analysis revealed that difficulty with taking off socks or stockings on the WOMAC scale is significantly associated with less knee flexion range of motion. Interestingly, patients with “Moderate/Severe PFOA” did not demonstrate increased odds of having difficulty with this task. It is plausible that patients with more severe PFOA may have developed compensatory strategies to perform this task without requiring high degrees of knee flexion. For example, to avoid pain and difficulties, patients with more severe PFOA and limited knee flexion range of motion could potentially take off their socks or stockings by flexing their hips and/or trunk instead of flexing their knees.

Physical disability and functional impairments have frequently been reported for patients with knee OA.[34, 35] As such, a number of factors including impairment of the lower limb have been proposed as possible explanations for such functional limitations.[36–38] For instance, lower limb muscle weakness, particularly affecting the quadriceps, has been suggested as a risk factor which is associated with both pain severity and disability in patients with knee OA.[39–42] In addition, quadriceps weakness may be related to disease progression over the lateral PF compartment and worsening of symptoms and functional limitations over time.[43] Limited knee flexion range of motion has also been associated with increased disability in this patient population.[38] The findings from the current study suggest that compared to patients with TFOA who have no PFOA, those with coexisting “Moderate/Severe” PF disease demonstrate significantly lower knee extension strength and diminished total knee range of motion. Given that our analyses were adjusted for severity of radiographic TFOA, the group differences in knee extension strength and range of motion could be attributed to the severity of PFOA.

The limitations in function reported in individuals with more severe PFOA in our study are consistent with those reported previously.[5, 6, 9] Englund and Lomander[9] reported more symptoms, lower functional status, and worse knee-related quality of life for patients with combined PF and TFOA many years after undergoing meniscal resection. However, Englund and Lomander did not examine the potential impact of PF disease severity on these findings. The current study adds to previous work by demonstrating that the severity of coexisting PF disease in individuals with TFOA may be associated with additional increases in symptoms and limitations with specific activities of daily living beyond those caused by severity of TFOA. Our observations also corroborate the findings by Duncan and colleagues[5] who reported that higher radiographic OA severity in the PF compartment is independently associated with lower functional scores.

Consistent with our findings, Duncan and colleagues[6] also reported a strong association for functional difficulty with going downstairs for patients with isolated PFOA compared to those with normal knee radiographs. However, these investigators also reported greater difficulty with getting in/out of the bath and getting in/out of the car for patients with more severe isolated PFOA which was not evident in our cohort. This discrepancy may be the result of using different reference comparison groups. Whereas we used a comparison cohort with TFOA, Duncan and colleagues used a control group with no radiographic disease. As such, a good proportion of our patients in the “No PFOA” group had difficulty with getting in/out of a car (36.4%), getting in/out of bath (18.2%) and going downstairs (45.5%) due to their TFOA. Therefore, using a reference comparison group with greater impairments and functional deficits may have prevented us from showing a relationship between severity of PFOA with less demanding bilateral activities such as getting in/out of a bath or a car which require only 50% weightbearing by the symptomatic limb. On the other hand, the observed association between more severe PF disease and difficulty with going downstairs in our study may be due to the higher weightbearing requirements of this single limb activity which requires 100% weightbearing by the symptomatic limb.

From a biomechanical perspective, stair climbing places extremely high demands on the quadriceps and requires greater range of knee motion when compared to level walking. For instance, it has been reported that the demands placed on the quadriceps while climbing stairs could be three times higher than those encountered during walking on a flat surface.[44] In addition, peak weight-bearing knee flexion angles of 70 to 92 degrees are required for climbing stairs, compared to only 15 to 20 degrees needed during walking on a flat surface.[33, 45] Although the available knee range of motion reported for our cohort is adequate for meeting the demands of stair climbing, the reduced knee extension strength associated with more severe PF disease may make climbing stairs more difficult. To explore this hypothesis, a post-hoc analysis of the association between knee extension strength and reports of difficulty with going downstairs was performed. The results of this analysis revealed that difficulty with going downstairs on the ADLS scale is significantly associated with lower knee extension strength.

Greater knee flexion angles and higher quadriceps demands during weight-bearing tasks have been previously associated with greater PF joint compression forces[31] and pain[46] in individuals with PF dysfunction. Therefore, it could alternatively be argued that the individuals with PF disease in our study may have reduced the degree to which they flexed their knees during stair climbing in an attempt to lessen the compressive forces and pain. Such compensatory reduction in knee flexion during stair descent will most likely contribute to the difficulties reported with going downstairs in this patient population. However, this assertion cannot be verified in the current study given the lack of quantitative information about how the stair descent task was actually performed by the patients. Future biomechanical analyses are needed to quantify the degree of knee flexion during stair descent in patients with co-existing TF and more severe PFOA.

Limitations

Although, progression of disease severity could lead to loss of functional independence and poor quality of life, the cross-sectional nature of this study limits our ability to predict whether progression of PF joint disease is associated with change in knee-specific impairments and functional limitations. A longitudinal study would be needed to tease out the potential influence of PF joint disease progression on lower limb impairments and functional limitations. We also had a small number of subjects in our “No PFOA” group (N = 33) which may have limited our findings. Another limitation of our study is that information about symptoms and functional limitation were taken from self-report measures that represent the patient’s perception of their ability to perform a given task. Future work should consider performance-based measures of function to better quantify potential group differences in functional deficits.

CONCLUSION

Our results indicate that presence of more severe coexisting PFOA is associated with significantly lower knee extension strength and range of motion, as well as difficulty with going down stairs. Therefore, it appears that knees with more severe PF disease demonstrate features distinct from those observed in TFOA in isolation or in combination with mild PF disease. As structural abnormalities and symptoms related to the PFOA are frequently observed in individuals with symptomatic knee OA,[3, 4] epidemiological and clinical studies of knee OA should also consider evaluation of the PF compartment. In addition, targeted interventions designed to treat the PF joint should be considered to mitigate functional deficits present in this patient population.

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SIGNIFICANCE & INNOVATION

- The potential clinical impact of severity of coexisting patellofemoral joint OA along with tibiofemoral OA in individuals with symptomatic knee OA has not been fully clarified.
- Individuals with more severe coexisting patellofemoral joint disease demonstrate features distinct from those observed in tibiofemoral OA in isolation or in combination with mild patellofemoral OA.
- More severe patellofemoral OA seems to be associated with lower limb impairments of reduced knee extension strength and limitations of knee range of motion as well as increased difficulty with going downstairs.
- Targeted interventions designed to treat the patellofemoral joint should be considered to mitigate functional deficits and impairments in individuals with coexisting patellofemoral OA.

Table 1

Comparisons of patient characteristics.

Demographics	No PFOA (N = 33)	Mild PFOA (N = 63)	Moderate/Severe PFOA (N = 71)	P-value
Age (years)	60.5 (8.1)	65.6 (9.1) *	63.8 (8.7)	0.03
Female (%)	21 (63.6)	36 (57.1)	55 (77.5) †	0.04
Height (cm)	168.0 (8.3)	168.0 (10.2)	168.0 (9.3)	0.99
Weight (kg)	79.4 (13.0)	86.7 (21.1)	89.6 (17.4) *	0.03
BMI (kg/m^2)	28.1 (4.2)	30.7 (7.2) *	31.9 (6.2) *	0.02
Tibiofemoral Joint Radiographic Severity [1]				
Grade II (%)	12 (36.4)	5 (7.9) *	9 (12.6) *	
Grade III (%)	15 (45.5)	36 (57.1)	31 (43.7)	0.02
Grade IV (%)	6 (18.2)	22 (34.9)	31 (43.7) *	
Patellofemoral Joint Radiographic Severity				
Grade 0 (%)	7 (21.2)	0	0	
Grade I (%)	26 (78.8)	0	0	
Grade II (%)	0	63 (100)	0	0.001
Grade III (%)	0	0	54 (76.1)	
Grade IV (%)	0	0	17 (23.9)	

PFOA = Patellofemoral osteoarthritis; Values are mean (SD) or N (%).

[1] All patients had to have at least a grade II tibiofemoral OA to be included in the study.

* Significantly different than “No PFOA” group

† Significantly different than “Mild PFOA” group

Table 2

Comparisons of the adjusted Western Ontario and McMaster Universities (WOMAC) OA Index, the Activities of Daily Living Scale (ADLS) and the knee-specific impairments.

	No PFOA (N = 33)	Mild PFOA (N = 63)	Moderate/Severe PFOA (N = 71)	P-value
WOMAC $_{\text{Total Score}}$	25.8 (13.8)	28.0 (14.8)	32.5 (17.1)	0.64
WOMAC $_{\text{Physical Function Score}}$	17.4 (10.6)	20.2 (11.4)	22.5 (12.7)	0.60
WOMAC $_{\text{Pain Score}}$	5.5 (2.6)	5.0 (3.0)	6.5 (3.8)	0.17
WOMAC $_{\text{Stiffness Score}}$	2.9 (1.6)	2.8 (1.4)	3.4 (1.7)	0.48
Activities of Daily Living Scale (ADLS)	71.5 (14.7)	67.1 (17.5)	62.7 (18.3)	0.50
Knee Extension Strength (Nm/Kg)	1.8 (0.5)	1.7 (0.5)	1.4 (0.5) *	0.03
Flexion Range of Motion (degrees)	136.9 (7.8)	130.8 (10.9) *	126.8 (10.9) *	0.01
Extension Range of Motion (degrees)	−3.3 (4.8)	−5.0 (6.0)	−6.0 (6.1)	0.32
Total Knee Range of Motion (degrees)	133.5 (10.7)	125.8 (13.0) *	120.8 (14.4) *	0.01

PFOA = Patellofemoral Osteoarthritis; Values are mean (SD).

All analyses were adjusted for age, gender, BMI and radiographic tibiofemoral joint disease severity.

*Significantly different than “No PFOA” group

Table 3

Absolute frequencies, percentages and the associations between severity of patellofemoral joint osteoarthritis and moderate/severe/extreme levels of symptoms or difficulty performing the tasks on the Western Ontario and McMaster Universities (WOMAC) index.

Pain Subscale	Reference Group No PFOA Frequency (%)	Mild PFOA Frequency (%)	Mild PFOA Odds Ratio (95% CI)[1]	Moderate/Severe PFOA Frequency (%)	Moderate/Severe PFOA Odds Ratio (95% CI)[1]
Pain walking on a flat surface?	8 (24.2%)	20 (31.7%)	1.5 (0.5,4.2)	20 (28.2%)	0.9 (0.3,2.6)
Pain going up or down stairs?	16 (48.5%)	34 (54.0%)	1.1 (0.4,2.9)	52 (73.2%)	1.7 (0.7,4.4)
Pain at night while in bed?	6 (18.2%)	12 (19.0%)	0.9 (0.3,2.9)	22 (31.0%)	1.3 (0.4,4.0)
Pain while sitting or lying?	6 (18.2%)	7 (11.1%)	0.8 (0.2,3.0)	15 (21.1%)	1.0 (0.3,3.2)
Pain while standing?	16 (48.5%)	13 (20.6%)	0.2 (0.1,0.6)*	27 (38.0%)	0.2 (0.1,0.7)*
Stiffness Subscale					
Stiffness after waking up in the morning?	17 (51.5%)	27 (42.9%)	0.8 (0.3,1.9)	41 (57.7%)	0.7 (0.3,2.0)
Stiffness after sitting/lying or resting during the day?	13 (39.4%)	27 (42.9%)	1.3 (0.5,3.7)	39 (54.9%)	1.3 (0.5,3.5)
Function Subscale					
Difficulty going down stairs?	15 (45.5%)	32 (50.8%)	0.9 (0.4,2.5)	49 (69.0%)	1.9 (0.7,4.9)
Difficulty going up stairs?	11 (33.3%)	32 (50.8%)	2.0 (0.8,5.4)	41 (57.7%)	1.6 (0.6,4.2)
Difficulty getting up from a sitting position?	10 (30.3%)	29 (46.0%)	1.6 (0.6,4.7)	40 (56.3%)	1.7 (0.6,4.9)
Difficulty while standing?	9 (27.3%)	17 (27.0%)	0.8 (0.3,2.2)	22 (31.0%)	0.7 (0.2,2.0)
Difficulty while bending to the floor?	13 (39.4%)	36 (57.1%)	2.3 (0.9,6.3)	39 (54.9%)	1.8 (0.7,4.7)
Difficulty with walking on a flat surface?	6 (18.2%)	15 (23.8%)	1.2 (0.4,3.8)	20 (28.2%)	1.2 (0.4,3.7)
Difficulty getting in or out of the car?	12 (36.4%)	26 (41.3%)	1.1 (0.4,3.0)	31 (43.7%)	0.6 (0.2,1.8)
Difficulty going shopping?	9 (27.3%)	25 (39.7%)	1.2 (0.4,3.5)	21 (29.6%)	0.5 (0.2,1.5)
Difficulty putting on socks or stockings?	5 (15.2%)	21 (33.3%)	2.2 (0.7,7.2)	19 (26.8%)	1.3 (0.4,4.5)
Difficulty getting out of bed?	13 (39.4%)	17 (27.0%)	0.6 (0.2,1.5)	27 (38.0%)	0.7 (0.3,1.9)
Difficulty with taking off socks or stockings?	4 (12.1%)	24 (38.1%)	4.3 (1.2,16.1)*	20 (28.2%)	2.0 (0.6,7.3)
Difficulty while lying in bed?	3 (9.1%)	11 (17.5%)	2.5 (0.6,11.3)	14 (19.7%)	2.1 (0.5,8.9)
Difficulty getting in or out of the bathtub?	6 (18.2%)	25 (39.7%)	2.4 (0.8,7.5)	33 (46.5%)	2.4 (0.8,7.5)
Difficulty while sitting?	5 (15.2%)	11 (17.5%)	1.2 (0.3,4.2)	18 (25.4%)	1.3 (0.4,4.6)
Difficulty with getting on or off the toilet?	10 (30.3%)	19 (30.2%)	0.7 (0.2,2.1)	28 (39.4%)	0.9 (0.3,2.5)
Difficulty with heavy household chores?	18 (54.5%)	37 (58.7%)	0.9 (0.3,2.6)	50 (70.4%)	1.0 (0.4,2.7)
Difficulty with light household chores?	6 (18.2%)	16 (25.4%)	1.1 (0.3,3.9)	17 (23.9%)	0.7 (0.2,2.4)

[1] All analyses were performed in references to the “No PFOA” group and were adjusted for age, gender, BMI and radiographic tibiofemoral joint disease severity.

†Significant at $P < 0.05$

Table 4

Absolute frequencies, percentages and associations between severity of patellofemoral joint osteoarthritis and moderate/severe/extreme levels of symptoms or difficulty performing the tasks on the Activities of Daily Living Scale (ADLS).

	Reference Group No PFOA Frequency (%)	Mild PFOA Frequency (%)	Mild PFOA Odds Ratio (95% CI) [1]	Moderate/Severe PFOA Frequency (%)	Moderate/Severe PFOA Odds Ratio (95% CI) [1]
Pain effecting daily activity?	26 (78.8%)	47 (74.6%)	1.0 (0.3,3.2)	51 (71.8%)	0.4 (0.1,1.2)
Stiffness effecting daily activity?	20 (60.6%)	43 (68.3%)	1.8 (0.6,5.0)	50 (70.4%)	0.8 (0.3,2.4)
Swelling effecting daily activity?	12 (36.4%)	17 (27.0%)	0.7 (0.3,2.1)	27 (38.0%)	0.9 (0.3,2.3)
Giving way/buckling/shifting of knee effecting daily activity?	11 (33.3%)	23 (36.5%)	1.1 (0.4,3.1)	27 (38.0%)	1.3 (0.5,3.4)
Weakness affecting daily activity?	14 (42.4%)	30 (47.6%)	1.0 (0.4,2.6)	35 (49.3%)	1.0 (0.4,2.7)
Limping affecting daily activity?	14 (42.4%)	27 (42.9%)	0.9 (0.3,2.3)	29 (40.8%)	0.8 (0.3,2.1)
Limitations with walking?	10 (30.3%)	24 (38.1%)	1.1 (0.4,2.9)	28 (39.4%)	0.9 (0.3,2.5)
Limitations with going up stairs?	12 (36.4%)	32 (50.8%)	1.3 (0.5,3.6)	43 (60.6%)	1.3 (0.4,3.7)
Limitations with going down stairs?	14 (42.4%)	32 (50.8%)	1.1 (0.4,3.1)	53 (74.6%)	2.9 (1.0,8.1) *
Limitations with standing?	7 (21.2%)	16 (25.4%)	0.8 (0.3,2.7)	23 (32.4%)	1.1 (0.4,3.3)
Limitations with kneeling on the front of the knee?	23 (69.7%)	41 (65.1%)	1.2 (0.4,3.6)	60 (84.5%)	2.4 (0.7,8.0)
Limitations with squatting?	23 (69.7%)	45 (71.4%)	0.8 (0.3,2.6)	58 (81.7%)	1.2 (0.4,4.0)
Limitations with sitting with knee bent?	6 (18.2%)	18 (28.6%)	1.6 (0.5,5.1)	26 (36.6%)	2.0 (0.6,6.1)
Limitations with rising from a chair?	11 (33.3%)	29 (46.0%)	1.3 (0.5,3.9)	38 (53.5%)	1.4 (0.5,4.2)

[1] All analyses were adjusted for age, gender, BMI and radiographic tibiofemoral joint disease severity.

* Significant at $P < 0.05$