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Hip Abductor Weakness and Its Association with New or Worsened Knee Pain: the MOST Study

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Abstract

Objective: Hip abductors, important for controlling pelvic and femoral orientation during gait, may affect knee pain. We evaluated the relation of hip abductor strength to worsened or new-onset frequent knee pain (FKP). Given previously noted associations of knee extensor strength with osteoarthritis (OA) in women, we performed sex-specific analyses.

Methods: We used data from the Multicenter Osteoarthritis Study (MOST). Hip abductor and knee extensor strength was measured. Knee pain was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire and a question about FKP at baseline (144-month visit), and 8, 16 and 24 months thereafter. Knee pain outcomes were (1) worsened knee pain (2-point increase in WOMAC pain) and (2) incident FKP (answering 'yes' to the FKP question among those without FKP at baseline). Leg-specific analyses tested hip abductor strength as a risk factor for worsened and new FKP, adjusting for potential covariates. Additionally, we stratified by knee extensor strength (high vs. low).

Results: Among women, compared to the highest quartile of hip abductor strength, the lowest quartile had 1.7 (95% confidence interval [95% CI] 1.1-2.6) times the odds of worsened knee pain;

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significant associations were limited to women with high knee extensor strength (odd ratio 2.0 [95% CI 1.1-3.5]). We found no relation of abductor strength to worsening knee pain in men or with incident FKP in men or women.

Conclusion: Hip abductor weakness was associated with worsening knee pain in women with strong knee extensors, but not with incident frequent knee pain in men or women. Knee extensor strength may be necessary, but not sufficient, to prevent pain worsening.

Keywords

Pain; muscle strength; knee OA; hip abductor weakness

Introduction

Knee osteoarthritis (OA) and knee pain are highly prevalent in older adults and lead to poor function and increased disability. There is a need to identify modifiable risk factors that can be targeted in interventions in this population. Exercise and strength training are recommended by clinical guidelines as a first line of treatment for knee OA. Knee extensor weakness has been extensively studied as a risk factor for knee OA and knee pain (1-6). Other muscles in the lower extremity have also been implicated in the knee OA disease process, but limited data exist on their relation to knee pain.

Hip abductor weakness and decreased muscle volume are present in adults with knee OA (7-10). Hip abductors are important for controlling the orientation of the pelvis on top of the femur and the alignment of the femur relative to the tibia when weightbearing, both of which affect knee mechanics. Weakness of these muscles may increase pelvic drop, a movement thought to contribute to knee joint loading and pain (11, 12), although direct measurements of the knee adduction moment, a primary variable of joint loading, in individuals with hip abductor weakness do not support this assertion (13-15). Nonetheless, relationships between hip abductor weakness and knee pain and function have been reported in individuals preceding (16) or following (17) total knee arthroplasty. In individuals with knee OA, studies demonstrate that strengthening hip abductors leads to reduced knee pain and improved function (18-21).

Hip abductor weakness could be instrumental in the development or worsening of knee pain. Cross-sectional and interventional studies cannot distinguish whether the weakness is a result of or contributor to the development of knee pain. Longitudinal studies are necessary to elucidate relationships between this potentially modifiable factor and risk for pain. To date, no studies have investigated the relation of hip abductor weakness to new-onset or worsening knee pain. Chang et al reported greater baseline hip abductor strength was associated with reduced risks of cartilage worsening and function (repeated chair stands and self-reported function) (22); however, they did not assess relations with knee pain.

While evaluations often focus on weakness in individual muscles, such as the hip abductors, the observed weakness may indicate overall decreased muscle strength due to deconditioning and thus may not be muscle specific. Therapeutic interventions are frequently designed to address weakness in individual muscles noted during evaluation, emphasizing the importance of a thorough evaluation. Currently, no studies have investigated the contribution of hip abductor weakness to knee pain while considering the presence or absence of knee extensor muscle weakness.

Thus, the purpose of this study was to evaluate the longitudinal relation of hip abductor strength to worsened or new-onset of knee pain. As knee extensor strength is known to have a sex-specific effect on knee pain, we analyzed this relationship in the entire cohort and separately for women and men. We also evaluated this relationship with and without stratifying by knee extensor strength to investigate if any relationship noted is specific to the hip abductor muscles or more generally a reflection of overall muscle weakness.

Patients and Methods:

Study Sample

We used data from the Multicenter Osteoarthritis (MOST) Study. The MOST study is a prospective, observational, National Institutes of Health-funded cohort study of risk factors for the incidence and progression of knee OA (23). The original cohort was enrolled between 2003 and 2005 at the Iowa City, Iowa and Birmingham, Alabama study sites. Eligible participants were age 50-79 at the initial study visit and were at high risk of symptomatic knee OA defined as either having knee pain, being overweight, having a history of knee injury or surgery. At 144 months, participants from the original cohort without end-stage knee OA were invited to return for a study visit. This 144-month study visit for the original cohort was the ‘baseline’ visit for this analysis. At this same time, a new cohort was recruited. Eligibility for the new cohort included individuals, aged 45-69 years, without severe or constant knee pain, and with at most mild radiographic OA (all Kellgren-Lawrence ≤ 2). Additional exclusion criteria for hip and knee strength testing were high blood pressure on the day of the exam; any history of a brain aneurysm; cerebral hemorrhage in the past 6 months; knee or hip replacement or back surgery in the previous 3 months; heart attack or cataract surgery in the past 6 weeks; or groin hernia that has not been operated on. This initial study visit for the new cohort was the ‘baseline’ visit for this analysis. There was considerable overlap between the two cohorts as many of the original cohort still did not have OA and many in the new cohort had mild OA. The MOST study was approved by the local institutional review board at each site, and all participants gave informed consent.

Hip abductor and knee extensor strength assessment

At the baseline visit (144-month visit for the original cohort, initial visit for the new cohort), participants had hip abductor and knee extensor muscle strength measured in each leg. Briefly, hip abductor and knee extensor strength were measured with the participant seated in the chair of a HUMAC NORM Testing and Rehabilitation System (Computer Sports Medicine, Inc., Stoughton, MA). For assessment of isometric hip abductor strength, the chair was positioned with the seat back at approximately 15 degrees from horizontal. An additional leg rest extension was provided to position the knees in neutral extension. A custom-built device to measure force with a load cell (MLP-150, Transducer Techniques, Temecula, CA) was positioned at the level of the lateral femoral epicondyle. The distance between the greater trochanter and the location of the load cell was measured as an estimation of lever arm distance. Force was multiplied by this distance to obtain the torque measurement of hip abductor strength. A wide Velcro strap was placed at the level of the anterior superior iliac spines and tightened snug to stabilize the pelvis during testing. Legs were positioned shoulder width apart with the toes pointing upward toward the ceiling. Contralateral to the hip being tested, a large padded block was secured to maintain position of the contralateral leg. Individuals were instructed to “push” as hard as they could against a stationary padded bar positioned at the lateral femoral epicondyle of the knee. They maintained the contraction for approximately 3 seconds before resting. The measurement was repeated 3 times with 10 seconds between each trial. Participants were provided with the opportunity to practice at about 50% effort to become accustomed to the procedures before data were recorded at full effort. Verbal encouragement was provided during each trial. Test-retest reliability was assessed in 60 participants tested two times, approximately 7 days apart. The intraclass correlation coefficient (ICC) for hip abduction strength was 0.80 with a 95% confidence interval (95% CI) of ±0.09.

As a measure of knee extensor strength, we used the one-repetition maximum isotonic knee strength obtained as part of the larger study using the torque motor of the HUMAC NORM testing system. Individuals were positioned within the HUMAC NORM with the seat back positioned at 85 degrees relative to horizontal with the thigh strapped to the seat. Participants were instructed to fully extend the knee from a position of approximately 90 degrees flexion by pushing as hard and as fast as they could. Resistance was increased until the participant was unable to complete the full range of motion. The highest load participants were able to move through the full range of motion was considered their knee extensor strength. Participants were given 30 seconds of rest between repetitions to minimize muscle fatigue. The ICC for this measurement was 0.80 with an approximate 95% CI width of ± 0.09.

Assessment of knee pain

Knee pain was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire (24). WOMAC was administered at the baseline visit for this analysis and then 8, 16 and 24 months later. Frequent knee pain (FKP) was assessed by asking the question, “Have you had knee pain, aching, or stiffness on most of the last 30 days?” We then characterized two knee pain outcomes. First, using the WOMAC pain subscale, we defined worsened as an increase in pain score by at least 2 on the 0-20 scale (25). We characterized each knee as having worsened pain if reported pain was worse than baseline for at least 2 of the 3 follow-ups. Among those who did not report FKP at baseline, we characterized the knee as having new FKP if they responded ‘yes’ to the frequent knee pain question for at least 2 of the 3 follow-ups. Knees with WOMAC pain greater than 18 or with FKP at baseline were also excluded from the individual analyses.

Statistical analysis

We carried out leg-specific analyses (i.e., one participant could contribute two observations) using logistic regression to assess hip abductor weakness (sex-specific quartiles) as a risk factor for ipsilateral worsened (WOMAC) and new-onset FKP, accounting for the correlation between limbs with Generalized Estimating Equations (GEE) and adjusting for age, sex, body mass index (BMI), race (White vs. non-White), depressive symptoms (using the Center for Epidemiological Studies Depression Scale >15) (26, 27), and radiographic tibiofemoral OA (KL ≥ grade 2) in that knee. Baseline WOMAC pain score was also accounted for as a continuous variable in the WOMAC pain worsening analyses. Analyses were first conducted in the entire cohort and then separately for women and men since sex-specific differences in the effect of muscle weakness on OA outcomes have been reported (1-4). Participants were excluded from analyses if they were missing outcome measurements or covariates. All analyses were conducted in SAS 9.4 with an alpha of .05, two-sided.

We were also interested in the relation of hip abductor strength to knee pain while accounting for knee extensor strength. Because hip abductor strength and knee extensor strength are highly correlated in our sample (r=0.7), including both in the same model has limitations. Instead, we stratified our analysis by knee extensor strength (high vs. low using the median value, which was 37 Nm for women and 60 Nm for men). This approach allowed us to evaluate the relation of hip abductor strength to pain in those with stronger knee extensors (greater than the median) and those with weaker knee extensors (less than the median).

Analyses of lower extremity muscle strength often divide the strength values by body mass and may divide by a measure of height as well. Normalizing data by dividing by body mass and/or height introduces an interaction without separately assessing the variables in the interaction (28-30). Therefore, we choose not to normalize strength values.

Results:

Of the 3447 participants in the MOST study, participants or knees were removed from analysis for multiple reasons. 1058 participants were removed for not having hip abductor force; these were due to exclusion factors or strength testing equipment not being available. 153 participants had missing or inconsistent lever arm (i.e., thigh length) measures. After removing ineligible knees, the remaining knees with missing covariates were removed; the majority of these were missing knee extensor strength (Figure 1). 2167 and 2028 participants contributed 4142 and 3993 knees, respectively, to the WOMAC pain and FKP analyses. Characteristics of the participants are in Table 1.

In the full cohort, compared to the highest (strongest) quartile of hip abductor strength, the lowest quartile (weakest) was associated with 1.5 (95% CI 1.1, 2.0) times greater odds of worsened knee pain (Table 2). There was also a significant linear trend across quartiles of hip abductor strength (p=0.01). There was no relation between hip abductor strength and incident FKP in the full cohort.

In sex-specific analyses, among women compared to the highest (strongest) quartile of hip abductor strength, the lowest quartile (weakest) was associated with 1.7 (95% CI 1.1, 2.6) times greater odds of worsened knee pain (Table 3). There was also a significant linear trend across quartiles of hip abductor strength (p=0.02). There was no relation between hip abductor strength and incident FKP in women. In men, there was no relation to either pain outcome (Table 4).

In participants with greater than the median knee extensor strength, compared to the highest (strongest) quartile of hip abductor strength, the lowest quartile (weakest) was associated with 1.5 (95% CI 1.0, 2.4) times greater odds of worsened knee pain (Table 5); p for linear trend = 0.04. In women with high knee extensor strength, compared to the highest (strongest) quartile of hip abductor strength, the lowest quartile (weakest) was associated with 2.0 (95% CI 1.1, 3.5) times greater odds of worsened knee pain (Table 5); p for linear trend = 0.03. There was no relation in women with either high or low knee extensor strength to incident FKP. In men, there was no relation in either the high or low knee extensor strength group to either pain outcome.

Discussion

This study evaluated the relation of hip abductor strength to worsening or new onset of frequent knee pain, with and without stratifying by knee extensor strength. In women, hip abductor weakness was strongly associated with WOMAC knee pain worsening. When stratifying by knee extensor strength, this effect persisted in women with stronger, but not in those with weaker, knee extensor muscles. In men, however, there was no association between hip abductor strength and WOMAC knee pain worsening. In neither women nor men was hip abductor strength associated with incidence of frequent knee pain. Overall, we found differences in effect between women and men highlighting the importance of using sex-stratified analyses especially in musculoskeletal conditions with known sex differences.

Our hip abductor strength values and distributions were generally consistent with those in the literature (22, 31). Our values for knee extensor strength were lower than in the literature and lower than our measure of hip abductor strength. This is likely attributable to differences in methods. We used an isotonic one-repetition maximum measurement for knee extensor strength which may result in slightly lower values than would have been obtained with an isometric measurement. As we do not compare between hip abductor and knee extensor strength, the measurement differences are unlikely to impact our findings.

Hip abductor weakness has been hypothesized to increase contralateral pelvic drop, a movement thought to contribute to knee joint loading and pain (11, 12). This presumed mechanism whereby abductor weakness increases the knee adduction moment (KAM) during walking, a primary variable of joint loading, has not been supported (13-15). While hip abductor weakness has been correlated with peak pelvic drop (32), strength alone does not determine movement patterns. With our data, we were unable to determine how hip abductor weakness affected KAM or movement patterns in our cohort.

Hip abductor strength is associated with WOMAC physical function (33) and does contribute uniquely to the explained variance in performance-based measures of physical function even after accounting for knee extensor strength (17, 34). Hip abductor strength has also been related to turning speed (35), a metric not typically captured during straight walking, providing a potential explanation for why hip abductor strength affects function without changing KAM during walking. Similarly, interventions that target hip abductor strength have been effective in reducing symptoms and improving function (16, 18, 19).

While hip abductor weakness was strongly associated with WOMAC knee pain worsening in women, there was no relation to incident FKP suggesting that these two measures capture different aspects of the pain experience. The WOMAC pain subscale focuses on the difficulty caused by pain during different activities and at rest; FKP focuses on frequency of knee pain. An individual could have increased difficulty with activities due to pain (worsened WOMAC pain), without having pain more often (incident FKP). In our sample, we had twice as many individuals experience worsened WOMAC pain than individuals who had incident FKP.

The sex difference in the effect of hip abductor strength is consistent with findings of Chang et al (22). Hip abductor strength may be more important for women due to their structure, movement patterns, and/or an increased need for muscle to stabilize joints. For example, the female pelvis is wider and broader than the male pelvis (36-38); women typically have more hip anteversion and knee valgus than men (39). During walking, women tend to maintain the pelvis in more anterior pelvic tilt (40) and have greater excursion of the pelvis in the frontal (41-43) and transverse planes (42-44). Women may be more flexible than men (45) suggesting more reliance on muscle strength for stability, although data on this is not consistent (46). The combined effect of these differences may indicate both a need for greater muscle strength due to structural differences and a greater reliance on muscle strength for joint stability in women than in men.

The relationship of hip abductor weakness to worsening knee pain was affected by knee extensor strength in women. In the group with low knee extensor strength, there was no relation between hip abductor strength and pain; however, in the group with high knee extensor strength, individuals with hip abductor weakness were at increased risk of worsened knee pain. Chang et al noted a similar effect of hip abductor strength on structural damage and function (22). While our findings suggest that hip abductor strength may be uniquely important in those with strong knee extensors, risk factors for disease are often better detected in those who have few other risk factors, a concept underlying the rich contributions of groups with particular dietary habits (e.g., Seventh-day Adventists) to our understanding of risk factors for heart disease (47, 48). Those with strong knee extensors constitute those without a major risk factor for knee pain. Even so, our findings highlight that, while knee extensor strength is necessary, it may not be sufficient. Intervention programs targeted at reducing risk of knee pain should address both hip abduction and knee extension.

The study findings conducted in individuals with or at risk of knee OA are generalizable to similar populations, but may not generalize to a younger cohort. Similarly, the use of study-specific quartiles instead of pre-defined cutpoints may limit generalizability to other study populations. Other limitations exist. The impact of hip abductor strength on knee pain may depend on the location of knee pain; subclassifying the individuals based on knee pain location may demonstrate different relationships. The use of isometric hip abductor strength measured in a single hip position may not fully capture hip strength as used in functional activities, especially our selected position of neutral hip rotation. Knee extensor strength was measured isotonically, not isometrically, potentially influencing our results and interpretation; the motion captured may also not reflect strength during function given the seated position. The WOMAC threshold used to define worsened may not capture all worsening experiences. The limited number of cases, especially for incident FKP, may have reduced our ability to detect small-to-moderate associations.

Conclusion

Hip abductor weakness is associated with worsening knee pain in women, but not men, in this cohort. Hip abductor weakness was not associated with incident FKP in either women or men. A focus on strength beyond that of knee extensors alone may provide a comprehensive understanding of how lower extremity muscle strength affects knee pain.

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Significance:

- Hip abductor strength affects pelvic orientation during gait and may alter moments across the knee.
- Hip abductor weakness increased knee pain in women, especially those with strong knee extensors.
- There was no association of hip abductor strength with knee pain in men.

Innovation:

- Few studies have examined the longitudinal association of hip abductor strength with knee pain even though it may be a target of rehabilitation strategies.

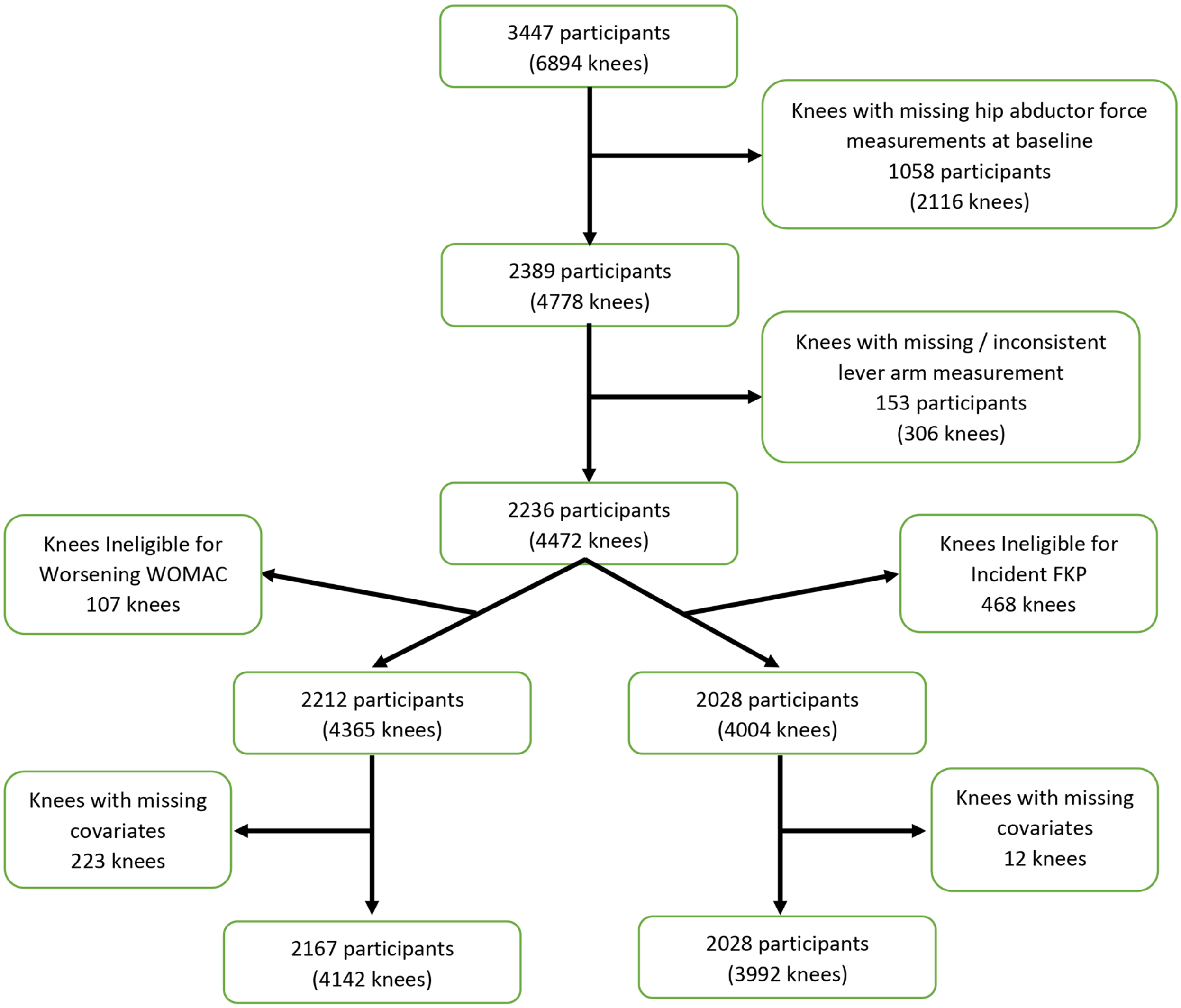

Figure 1.
Flow chart depicting derivation of participants included in the analysis for worsened WOMAC knee pain and for new-onset frequent knee pain (FKP).

Table 1:

Cohort characteristics: mean (standard deviation) or percent by sex.

	WOMAC Sample		FKP Sample	
	Women (n=2332 knees)	**Men (n=1810 knees)**	**Women (n=2221 knees)**	**Men (n=1771 knees)**
Age (years)	62.3 (9.9)	62.0 (10.0)	61.8 (9.8)	61.6 (9.8)
Body mass index (BMI) (kg/m^2)	28.6 (5.8)	29.7 (4.9)	28.5 (5.7)	29.7 (4.8)
Depressive Symptoms (%)	12.4	10	11.8	9.7
Race (% White)	77.2	82.1	77.6	82
Radiographic tibiofemoral OA (%)	28.1	21.8	30.2	23.1
Hip Abductor Strength (Nm)	73.26 (24.21)	114.51 (34.50)	74.20 (24.03)	114.80 (34.49)
Knee Extensor Strength (Nm)	41.47 (13.59)	67.10 (22.75)	41.94 (13.61)	67.64 (22.8)
WOMAC Pain at Baseline	2.2 (2.9)	1.8 (2.6)	2.1 (2.9)	1.7 (2.5)
WOMAC Pain Worsened (%)	13.8	13.5	12.8	13
New Frequent Knee Pain (%)	6.5	6.2	6.5	6.2

Table 2:

Relation of quartiles of hip abductor strength to knee pain.

Hip Abductor Strength Quartiles	Incident Frequent Knee Pain (n=3992; 255 events)		WOMAC Pain Worsening (n=4142; 567 events)	
	Frequency of Outcome n/N (%)	**OR* (95% CI)**	**Frequency of Outcome n/N (%)**	**OR* (95% CI)**
Q1 (Weakest) Women: 18.45-55.55 Men: 27.24-91.00	82/997 (8.2)	1.2 (0.8, 1.8)	189/1035 (18.3)	1.5 (1.1, 2.0)
Q2 Women: 55.56-72.36 Men: 91.01-110.95	59/998 (5.9)	1.0 (0.7, 1.4)	133/1036 (12.8)	1.1 (0.8, 1.5)
Q3 Women: 72.37-88.23 Men: 110.96-135.87	59/999 (5.9)	1.0 (0.7, 1.4)	126/1037 (12.2)	1.1 (0.8, 1.4)
Q4(Strongest) Women: 88.24-164.20 Men: 135.88-266.50	55/998 (5.5)	1.0 (referent)	119/1035 (11.5)	1.0 (referent)
P for Trend		0.5		0.01

*Odds ratio adjusted for age, sex, race, BMI, depressive symptoms, radiographic tibiofemoral OA, and baseline WOMAC pain score (for WOMAC analysis only).

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Table 3:

Relation of hip abductor strength to knee pain in women.

Hip Abductor Strength Quartiles	Incident Frequent Knee Pain (n=2221; 145 events)		WOMAC Pain Worsening (n=2332; 322 events)	
	Frequency of Outcome n/N (%)	OR* (95% CI)	Frequency of Outcome n/N (%)	OR* (95% CI)
Q1 (Weakest) 18.45-55.55	49/555 (8.8)	1.2 (0.7, 2.1)	111/583 (19.0)	1.7 (1.1, 2.6)
Q2 55.56-72.36	39/555 (7.0)	1.1 (0.6, 1.8)	83/583 (14.2)	1.4 (0.9, 2.1)
Q3 72.37-88.23	27/556 (4.9)	0.9 (0.5, 1.5)	71/584 (12.2)	1.3 (0.8, 1.9)
Q4 (Strongest) 88.24-164.20	30/555 (5.4)	1.0 (Referent)	57/583 (9.8)	1.0 (Referent)
P for Trend		0.5		0.02

*Odds ratio adjusted for age, sex, race, BMI, depressive symptoms, radiographic tibiofemoral OA, and baseline WOMAC pain score (for WOMAC analysis only)

Table 4:

Relation of hip abductor strength to knee pain in men.

Hip Abductor Strength Quartiles	Incident Frequent Knee Pain (n=1771; 110 events)		WOMAC Pain Worsening (n=1810; 245 events)	
	Frequency of Outcome n/N (%)	OR* (95% CI)	Frequency of Outcome n/N (%)	OR* (95% CI)
Q1 (Weakest) 27.24-91.00	33/442 (7.5)	1.1 (0.6, 2.1)	78/452 (17.3)	1.3 (0.8, 1.0)
Q2 91.01-110.95	20/443 (4.5)	0.8 (0.4, 1.4)	50/453 (11.0)	0.9 (0.6, 1.3)
Q3 110.96-135.87	32/443 (7.2)	1.0 (0.6, 1.8)	55/453 (12.1)	0.8 (0.6, 1.3)
Q4 (Strongest) 135.88-266.50	25/443 (5.6)	1.0 (Referent)	62/452 (13.7)	1.0 (Referent)
P for Trend		0.99		0.3

*Odds ratio adjusted for age, sex, race, BMI, depressive symptoms, radiographic tibiofemoral OA, and baseline WOMAC pain score (for WOMAC analysis only)

Table 5:

Relation of hip abductor strength quartiles to knee pain in those with knee extensor strength greater than median.

Hip Abductor Strength Quartiles	WOMAC Pain Worsening Full Cohort (n=2284; 277 events)		WOMAC Pain Worsening Women Only (n=1361; 155 events)	
	Frequency of Outcome n/N (%)	OR* (95% CI)	Frequency of Outcome n/N (%)	OR* (95% CI)
Q1 (Weakest)	45/235 (19.2)	1.5 (1.0, 2.4)	28/140 (20.0)	2.0 (1.1, 3.5)
Q2	62/490 (12.7)	1.2 (0.8, 1.7)	40/304 (13.2)	1.3 (0.8, 2.2)
Q3	77/681 (11.3)	1.0 (0.7, 1.5)	42/402 (10.5)	1.1 (0.7, 1.9)
Q4 (Strongest)	93/878 (10.6)	1.0 (referent)	45/515 (8.7)	1.0 (referent)
P for Trend		0.04		0.03

*Odds ratio adjusted for age, sex, race, BMI, depressive symptoms, radiographic tibiofemoral OA, and baseline WOMAC pain score. Median knee extensor values were 37 Nm for women and 60 Nm for men.