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Research Article

The Association of Obesity with Walking Independent of Knee Pain: The Multicenter Osteoarthritis Study

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Practice guidelines recommend addressing obesity for people with knee OA, however, the association of obesity with walking independent of pain is not known. We investigated this association within the Multicenter Osteoarthritis Study, a cohort of older adults who have or are at high risk of knee OA. Subjects wore a StepWatch to record steps taken over 7 days. We measured knee pain from a visual analogue scale and obesity by BMI. We examined the association of obesity with walking using linear regression adjusting for pain and covariates. Of 1788 subjects, the mean steps/day taken was 8872.9 ± 3543.4. Subjects with a BMI ≥ 35 took 3355 fewer steps per day independent of knee pain compared with those with a BMI ≤ 25 (95% CI -3899, -2811). BMI accounted for 9.7% of the variability of walking while knee pain accounted for 2.9%. BMI was associated with walking independent of knee pain.

1. Introduction

Walking for exercise is promoted by the Arthritis Foundation and the American College of Rheumatology for people with knee osteoarthritis (OA) in order to promote healthy living [1, 2]. Walking, among other types of physical activity, results in a reduction in knee pain and improvement in functional ability [3, 4]. Moreover, meeting physical activity guidelines through activities like walking can reduce the risk of death [5]. This is particularly noteworthy given that knee OA is associated with an increased risk of all-cause death [6] and given the rising prevalence of knee OA [7], this mortality risk poses significant public health implications.

For older adults with knee OA, knee pain is associated with difficulty walking [8], and often considered the primary culprit for low levels of physical activity and walking [9]. Obesity is also associated with difficulty walking and low levels of physical activity, and it is a primary risk factor for knee OA [10, 11]. About 1/3 of the United States population is obese with a BMI of at least 30 [12]. Furthermore, one in three obese adults have arthritis [13]. However, the association of obesity independent of knee pain with walking is not known. This is an important association to understand since weight loss is rarely prescribed to patients in practice [14] and instead clinicians typically focus on pharmacologic therapies for knee pain. While such practice is in contrast to treatment guidelines for OA, which recommend both weight loss intervention and pain management [15], evidence supporting these guidelines for an outcome of walking is sparse.

Hence, the purpose of our study is to examine the association of obesity with walking independent of knee pain. We hypothesized that obesity would be associated with walking independent of knee pain.

2. Materials and Methods

2.1. Sample. The cross-sectional study sample consisted of participants in the Multicenter Osteoarthritis (MOST) Study, a large multicenter longitudinal cohort study of community-dwelling subjects who have or are at high risk of knee OA [16]. The MOST sample included adults aged 50 to 79 years were recruited from the communities in and surrounding Birmingham, Alabama and Iowa City, Iowa. Inclusion criteria, based on risk for knee OA, included the presence of known risk factors, including being age over 50 years, female gender, previous knee injury or operation, and body weight in excess of the median weight for each age- and sex-specific group based on data from the Framingham OA Study [17]. The MOST study protocol was approved by the institutional review boards at the University of Iowa in Iowa City, University of California San Francisco, University of Alabama in Birmingham, and Boston University Medical Center.

2.2. Walking Subsample. Information on walking, pain, and obesity were collected at the 60-month MOST follow-up exam between June of 2009 and January of 2011. We restricted the analysis sample to those participants who had a minimum of 3 days of walking data since previous studies have found this to be the minimum number of days needed for a reliable estimate of physical activity [18].

Of the 2330 MOST participants attending the 60-month follow-up visit, 16% (377) did not agree to wear the StepWatch, and 2% (58) had monitor malfunctions. Of the remaining 1895 participants who wore the StepWatch, 94% (1788/1895) wore it for at least 3 valid days and represent the study sample. The StepWatch was worn for 3, 4, 5, 6, and 7 days by 3%, 4%, 7%, 12%, and 74% of participants, respectively. In general, participants included in this analysis were more likely to have better health status (e.g., lower BMI, depressive symptoms, less muscular weakness, and fewer comorbidities) compared with those not included in the analysis (data not shown).

2.3. Outcome

2.3.1. Walking. Following collection of clinic data where pain and body mass index (BMI) were collected, trained research assistants followed a written protocol to fit the StepWatch to the ankle of each study participant, and provided written and verbal instructions for putting on the device each morning and taking off the device at bedtime for the next 7 days.

The StepWatch is a small (70 × 50 × 20 mm; 38 g), waterproof, self-contained device that is worn on the ankle and records the number of steps taken every minute while providing no feedback to the user. The StepWatch has high concurrent validity in comparison with several reference standard measures of step frequency in older adults, high convergent validity in comparison with SF-36 scores among subjects with OA, and high test-retest reliability in adults [19, 20].

To determine if subjects wore the monitor long enough to be counted as a full day, we adopted a published method for processing accelerometry data [21], and defined ten hours of monitoring as the minimum amount of time needed to define a full day. The ten hour threshold represents more than 66% of waking hours and has been utilized as a threshold in studies of physical activity in the general adult population [22] and people with knee OA [21]. Time in use was counted from the first step recorded in the morning to the last step recorded in the evening. To exclude times subjects may have taken off the StepWatch during the day, we omitted times where the monitor registered no steps for 180 consecutive minutes during the day (see the appendix).

We quantified walking as the total number of steps taken per day on average as a continuous outcome. We calculated steps/day by totaling the number of steps taken each valid day of monitoring divided by the number of valid days.

2.4. Independent Variables

2.4.1. Knee Pain Severity. We measured knee pain severity as the average pain in the past 30 days on Visual Analogue Scale (VAS) ranging from 0 to 100. Subjects with two painful knees were categorized according to the VAS pain score of the more painful knee.

2.4.2. Obesity. We defined obesity using from BMI computed from standardized weight and height assessments. For analyses, we treated BMI as a continuous factor and a categorical factor by classified according to World Health Organization (WHO) categories [23].

2.5. Covariates. The following factors were treated as covariates based on existing literature linking them to function or physical activity [16, 24–27]: age, sex, living situation (alone or with someone), education (<college, ≥college), race (white, nonwhite), radiographic knee osteoarthritis (ROA) defined as a Kellgren and Lawrence score of ≥2 in the tibiofemoral joint, pain in the hip, ankle, or foot (present versus absent), comorbidities (0 versus ≥1) estimated with the modified Charlson comorbidity index [28], depressive symptoms (<16, ≥16) measured with the Center for Epidemiologic Studies Depression Scale (CES-D) [29], as well as knee strength in tertiles from the mean of four isokinetic knee extensor torque repetitions at 60 deg/sec measured in Newton-Meters (Cybex Inc. Medway, MA). All covariates were collected at the 60 month clinic visit except for living situation, which was collected at the baseline clinic visit.

2.6. Statistical Analysis. We examined levels of walking by employing descriptive statistics and plotted a histogram of the distribution of walking across our sample. Then, we examined the association of pain and BMI with walking. We first examined the independent effects of pain and BMI by calculating effects estimates and 95% confidence intervals (CI) using multiple linear regression adjusting for both pain and BMI (categorically) as well as for covariates. We also

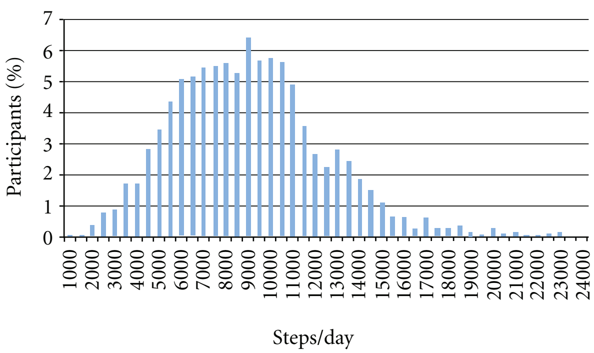

Figure 1: Histogram of steps taken per day. $N = 1788$.

adjusted for study site (Alabama or Iowa), to account for differences in data collection of StepWatch data and other study variables. We also examined the relative effect of pain and BMI with walking from partial correlation coefficients and standardized beta coefficients. We confirmed walking was normally distributed from visual inspection of Figure 1.

3. Results

The mean age the 1788 subjects included was 67.2 (sd = 7.7) years. Most participants' (36%) were overweight with a BMI ≥25 and <30 followed by 29% being obese with a BMI ≥30 and <35. The majority of subjects were women (60%) and white (90%). Table 1 lists characteristics of the subjects included in this study.

The average number of steps taken per day was 8872.9 (sd = 3543.4). Figure 1 shows the average step counts per day taken by participants.

More pain and higher BMI were associated with fewer steps taken per day (see Table 2). Each increase of 10 points on the VAS for pain was associated with taking 167 fewer steps per day. Subjects who were overweight (BMI ≥25 and <30), in obese class I (BMI ≥30 and <35), and in obese class II (BMI ≥35) took 989, 2069, and 3355 fewer steps per day compared with those with a healthy weight (BMI <25).

Mutually adjusting for pain and BMI along with covariates explained 28% of the variability of walking. Pain accounted for 2.9% of the variability while BMI accounted for 9.7% of the variability of walking. Similarly, a one standard deviation increase in pain accounted for a decrease of 0.07 of a standard deviation of walking, while a one standard deviation increase in BMI accounted for a decrease of 0.28 of a standard deviation of walking (see Table 3).

4. Discussion

We found BMI to be strongly associated with walking independent of knee pain. In particular, we found BMI to account for 9.7% of the variability of walking in comparison to only 2.9% for pain. These findings suggest that obesity has an important association with low levels of walking in people with or at high risk of knee OA independent of knee pain.

Knee pain accounted for little of the variability of walking when considered along with the effect of obesity. To put the relative effect of pain into perspective, knee pain accounted for only 10% of the total variability accounted by our model (pain, BMI, and all covariates). In contrast, obesity accounted for 35% of the total variability of the same model. We found a similar trend from the standardized beta coefficients with a one standard deviation increase in BMI accounting for more change in walking than the same increase in pain. This difference is notable given that knee pain is a major cause of functional limitation in people with knee OA [30–33]. However, from a conceptual perspective, the performance of physical function, such as walking speed, is distinctly different than how much physical activity one performs on a daily basis. Furthermore, previous studies have reported a weak association between knee pain and physical activity [34–36]. One possible reason for this is that people may have avoided walking for different reasons. Those with low levels of knee pain did not walk for fear of increasing their knee pain, while those with high knee pain were unable to walk due to current pain levels. Disentangling these associations is needed for future longitudinal studies.

We found obesity to have a strong association with walking, which has been reported previously in adults who are normal weight and obese and general population studies [37, 38]. Subjects in the highest BMI category walked over 3000 steps less per day than those in the lowest BMI category. The magnitude of this difference is clinically meaningful as it approaches a one standard deviation difference for walking in our sample. Given that our study is cross-sectional, we cannot infer causal direction, and association between obesity and walking is likely bidirectional. For instance, low levels of walking or physical activity could result in obesity. Similarly, people who are obese could have difficulty walking and hence have low levels of walking. Irrespective of the directionality, we found obesity to be strongly associated with walking independent of pain, which underscores the obesity epidemic in the United States and the importance of addressing obesity to avoid future poor health outcomes.

Step counts collected in our study cannot be compared with previous studies utilizing pedometers. Pedometers are known underestimate the number of steps taken by older adults up to 33% compared with a StepWatch [39], hence step counts in our study are higher than pedometer based studies. However, the average step counts in our study are comparable with smaller studies that employed the StepWatch in people with knee or hip OA and older adults [40, 41]. For instance, Winter et al. reported 30 people with radiographic knee OA walked 9350 steps/day, which is similar to our finding of 9194 and 8598 steps/day for men and women, respectively.

Our study has several strengths. First, we report daily walking from a large cohort of people with or at high risk of knee OA who wore a validated walking monitor. Second, this is the first study to report the association of obesity with walking independent of knee pain in people with or at high risk of knee OA using a well-validated objective monitor. There are some limitations to our study. First, subjects may have changed walking habits with the knowledge that their habitual walking was being recorded. Previous study suggests this "testing effect" is greatest when subjects wear an unsealed

Table 1: Summary of baseline characteristics across all subjects and within BMI categories.

	All subjects (n = 1788)	BMI <25 (n = 269)	BMI ≥25 and <30 (n = 641)	BMI ≥30 and <35 (n = 529)	BMI ≥35 (n = 352)
Knee pain (0–100) [Mean (sd)]	18.8 (20.9)	15.6 (18.3)	16.6 (19.5)	19.6 (20.8)	24.2 (23.8)
BMI [kg/m] [Mean (sd)]	30.7 (6.0)				
BMI <25 [%]	15				
BMI ≥25 and <30 [%]	36				
BMI ≥30 and <35 [%]	29				
BMI ≥35 [%]	20				
Age [Mean (sd)]	67.2 (7.7)	67.9 (7.8)	68.4 (8.0)	67.0 (7.6)	64.5 (6.7)
Sex [% women]	60	68	57	57	63
Living situation [% Lives alone]	17	16	16	17	18
Education [% ≥ College]	47	55	47	45	44
Race [% White]	90	96	92	89	85
Site [% Alabama]	38	37	38	37	39
Radiographic Knee Osteoarthritis [%]	54	41	52	55	71
Pain in the hip, ankle, or foot [%]	52	43	47	53	66
No Comorbidity [%]	59	66	61	59	51
Depressive Symptoms [Mean CES-D (sd)]	6.4 (6.8)	5.3 (5.8)	5.8 (6.1)	6.8 (7.3)	7.7 (7.6)
Knee extensor strength [N-M/kg] [Mean (sd)]	1.03 (0.41)	1.17 (0.41)	1.11 (0.43)	1.00 (0.37)	0.82 (0.33)

Table 2: Change in the number of daily steps attributed to pain and BMI after adjustment for covariates.

	Adjusted* beta [95% CI]
Knee Pain (10 unit increments on 0–100 VAS scale)	−166.8 [−245.5, −88.1]
BMI	
<25 "healthy weight"	Reference
≥25 and <30 "overweight"	−989.4 [−1437.0, −541.7]
≥30 and <35 "obese class I"	−2069.6 [−2540.1, −1599.2]
≥35 "obese class II-III"	−3355.1 [−3899.4, −2810.8]

* Mutually adjusted for pain and BMI as well as age, sex, living situation, education, race, study site, Radiographic Knee Osteoarthritis, pain in the hip, ankle, or foot, comorbidity, depressive symptoms, and isokinetic knee extensor strength.

monitor, that is, when subjects are aware of how many steps are being recorded [42–44]. We believe any increases in walking due to a testing effect were minimized since study participants did not know the number of steps that were recorded. Second, we acknowledge we employed few psychological measures as covariates in our analyses. We were limited to measures already collected in the MOST study and were not able to add measures of self efficacy or fear avoidance, which are likely associated with walking. Lastly, our sample consisted of people both with and at high risk of knee osteoarthritis, therefore, it is not clear if our findings are directly generalizable to those with knee OA. We performed a sensitivity analysis stratifying our sample by those with and without ROA and found similar effects for pain and obesity within each strata compared with our main findings.

5. Conclusion

We found BMI to be associated with walking independent of pain in the studied sample of people with or at high risk of knee OA. These findings support clinical practice guidelines that obesity is an important modifiable factor to intervene upon and particularly relevant for walking among people with or at high risk of knee OA. Future research should investigate the longitudinal association of BMI and knee pain with walking in order to better understand the temporal relationships between these factors.

Appendix

Previous literature to distinguish periods of inactivity from nonwear have employed monitors designed to measure all types of physical activity (Actigraph). These studies have employed thresholds of 60 minutes to 90 minutes of no activity to represent nonwear. However, it is not known if these same thresholds can be generalized to a monitor only measuring step counts, as periods of physical inactivity likely differ from periods of not walking worn by people with or at high risk of knee OA. One previous study of adult bariatric surgical candidates found a threshold of 120 minutes of no

Table 3: Percentage of variability of walking attributed to pain, BMI, and covariates and expected change in walking for each one standard deviation increase in pain, BMI, and continuous covariates.

	Partial R-square (%)	Standardized Beta*
Knee pain (0–100)	2.9	−0.08
BMI (continuous)	9.7	−0.28
Age	8.4	−0.28
Sex	0.3	
Living situation	0.1	
Education	0.0	
Race	0.0	
Site	2.1	
Radiographic Knee Ostearthritis	0.2	
Pain in the hip, ankle, or foot	0.0	
Comorbidity	2.4	
Depressive Symptoms	0.7	
Isokinetic knee extensor strength	1.6	0.17

*Calculated for continuous variables only.

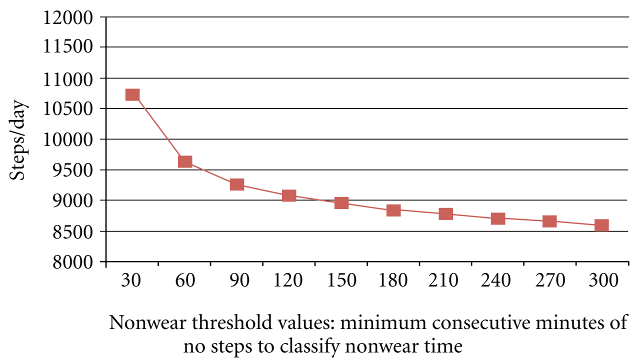

Figure 2

steps was suggested as nonwear time [45]. We examined how increases in threshold values of nonwear time changed reporting of the daily average wear time, steps, and time walking at a moderate intensity.

As threshold values of nonwear time increased, the monitor was counted as being worn for a greater duration of time. Subsequently, the average number of steps/day decreased. However, changes in steps/day did not change appreciably using threshold values of nonwear greater than 180 minutes. As a result, we employed a 180 minute threshold of no steps to distinguish periods of inactivity from not wearing the monitor (for more details see Figure 2).

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