ARTHRITIS & RHEUMATISM
Vol. 63, No. 11, November 2011, pp 3372–3382
DOI 10.1002/art.30562

Objective Physical Activity Measurement in the Osteoarthritis Initiative

Are Guidelines Being Met?

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Objective. **Osteoarthritis (OA) clinical practice guidelines identify a substantial therapeutic role for physical activity, but objective information about the physical activity of this population is lacking. The aim of this study was to objectively measure levels of physical activity in adults with knee OA and report the prevalence of meeting public health physical activity guidelines.**

Methods. **Cross-sectional accelerometry data from 1,111 adults with radiographic knee OA (49–84 years old) participating in the Osteoarthritis Initiative accelerometry monitoring ancillary study were assessed for meeting the aerobic component of the 2008 Physical Activity Guidelines for Americans (≥150 minutes/week moderate-to-vigorous–intensity activity lasting ≥10 minutes). Quantile regression was used to test median sex differences in physical activity levels.**

Results. **Aerobic physical activity guidelines were met by 12.9% of men and 7.7% of women with knee OA. A substantial proportion of men and women (40.1% and 56.5%, respectively) were inactive, having done no moderate-to-vigorous activity that lasted 10 minutes or more during the 7 days. Although men engaged in significantly more moderate-to-vigorous activity (average daily minutes 20.7 versus 12.3), they also spent more time in no or very-low-intensity activity than women (average daily minutes 608.2 versus 585.8).**

Conclusion. **Despite substantial health benefits from physical activity, adults with knee OA were particularly inactive based on objective accelerometry monitoring. The proportions of men and women who met public health physical activity guidelines were substantially less than those previously reported based on self-reported activity in arthritis populations. These findings support intensified public health efforts to increase physical activity levels among people with knee OA.**

Osteoarthritis (OA) is a major debilitating disease affecting more than 27 million people in the US (1).

The findings and conclusions reported herein are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the Osteoarthritis Initiative (OAI).

Supported in part by grants from the National Institute of Arthritis and Musculoskeletal and Skin Diseases (P60-AR-48098, R01-AR-055287, R01-AR-054155, and R21-AR-059412) and by the Falk Medical Research Trust. The OAI is a public-private partnership comprising 5 contracts funded by grants from the NIH (N01-AR-2-2258, N01-AR-2-2259, N01-AR-2-2260, N01-AR-2-2261, and N01-AR-2-2262), a branch of the Department of Health and Human Services, and conducted by the OAI Study Investigators. Private funding partners include Merck Research Laboratories, Novartis Pharmaceuticals Corporation, GlaxoSmithKline, and Pfizer, Inc. Private sector funding for the OAI is managed by the Foundation for the NIH.

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Dr. Eaton has received grant funding from Pfizer.

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Submitted for publication April 18, 2011; accepted in revised form July 19, 2011.

This number is expected to increase due to the growing obesity epidemic and the greater numbers of adults reaching older ages, when the prevalence of arthritis is highest (2–4). OA affecting the knee is currently a leading cause of disability in adults (1,5,6).

OA clinical practice guidelines identify a substantial therapeutic role for physical activity in bone and joint health (7). Recent guidelines from the Department of Health and Human Services now include people with arthritis in the physical activity recommendations (8). Among persons with knee OA, physical activity conveys disease-specific benefits. Randomized clinical trials show that physical activity programs are effective to reduce pain, improve physical performance, reduce depressive symptoms, and prevent or delay disability in knee OA (9–11). In addition, physical activity conveys general health benefits (12). Randomized clinical trials in the general adult population show that physical activity reduces mortality and risk of various chronic diseases and can improve disease-related symptoms and complications, such as pain, fatigue, functional limitation, and impaired sleep (8,13).

Despite important health benefits of being physically active, persons with arthritis are particularly inactive and are at risk for poor health outcomes (14,15). In a national US survey, 44% of persons with arthritis were classified as inactive (i.e., reporting no sustained 10-minute periods of moderate or vigorous physical activity in a typical week) compared to 36% of adults without arthritis (16). These estimates were based on self-reports of activity, which are prone to overestimation of activity intensity and time spent in physical activity (17). Thus, use of currently available statistics may lead to overestimates of physical activity levels among adults with arthritis. Objective evidence on physical activity in this population is needed to better understand the magnitude of the problem. The primary purpose of this study was to assess objectively measured physical activity levels of adults with knee OA and report the prevalence of public health physical activity guidelines being met among this population. A secondary purpose was to assess the effects of age, sex, and body mass index (BMI) on physical activity levels.

PATIENTS AND METHODS

Study population. The participants for this physical activity study were a subcohort of the Osteoarthritis Initiative (OAI), a prospective study investigating risk factors and biomarkers associated with the development and progression of knee OA. Participants in the OAI consist of men and women, ages 45–79 years at enrollment, with or at high risk to develop knee OA. Annual OAI evaluations began in 2004 at 4 clinical sites (Baltimore, Maryland; Columbus, Ohio; Pittsburgh, Pennsylvania; and Pawtucket, Rhode Island) and are currently ongoing (18). Approval was obtained from the institutional review board at each participating OAI site and at Northwestern University. Each participant provided written informed consent.

Individuals with rheumatoid or inflammatory arthritis were excluded from the OAI. Additional reasons for exclusion were as follows: findings of severe joint space narrowing in both knees on the baseline knee radiograph, or unilateral total knee replacement and severe joint space narrowing in the other knee; bilateral total knee replacement or plans to have bilateral knee replacement in the next 3 years; an inability to undergo 3.0T magnetic resonance imaging of the knee because of contraindications; positive pregnancy test; inability to provide a blood sample; use of ambulatory aides other than a single straight cane for $>50\%$ of the time during ambulation; comorbid conditions that might interfere with the ability to participate in a 4-year study; and current participation in a double-blind randomized trial. All OAI participants underwent knee radiography at baseline, using a fixed-flexion knee radiography protocol (19) including bilateral, standing, posteroanterior knee radiographs with knees flexed to 20–30° and feet in 10° of internal rotation using a Plexiglas positioning frame. Baseline radiographs were assessed by clinic readers and graded using the Osteoarthritis Research Society International (OARSI) atlas (20) of tibiofemoral osteophytes and joint space narrowing. At the baseline visit, 2,679 participants with radiographic evidence of knee OA (i.e., definite joint space narrowing, or OARSI atlas grade 1 or higher level of osteophytes) in one or both knees were identified, from the total OAI enrollment of 4,796 participants.

In a physical activity study, accelerometry data were collected on a subcohort of OAI participants with and without baseline radiographic OA, at the scheduled 48-month followup examination. Eligibility required a scheduled OAI 48-month followup visit between August 2008 and July 2010, with staggered starting months across the OAI sites. Of the 4,796 participants, 1,543 OAI participants had visits that preceded the physical activity study start date and 541 were deceased, did not return at 48 months, or withdrew from the OAI study. Of the remaining 2,712 eligible participants, 2,127 consented to participate in accelerometer monitoring (78.4%). Of these 2,127 participants, 1,223 had radiographic knee OA at baseline (see Figure 1). Accelerometry data were merged with OAI public data (from baseline to the 48-month examination) containing information on participant characteristics.

Accelerometry. Physical activity was measured at the OAI 48-month followup examination using an ActiGraph GT1M accelerometer, a small uniaxial accelerometer that measures vertical acceleration and deceleration (21). Uniaxial accelerometry validation studies against whole-body indirect calorimetry showed high correlation with metabolic equivalent ($r = 0.93$) and total energy expenditure ($r = 0.93$) (22). The accuracy (walking speed [23]) and test–retest reliability (24) of Actigraph accelerometers under field conditions have been established in many populations, including in persons with OA (25). Accelerometer output is an activity count, which is the weighted sum of the number of accelerations measured over a

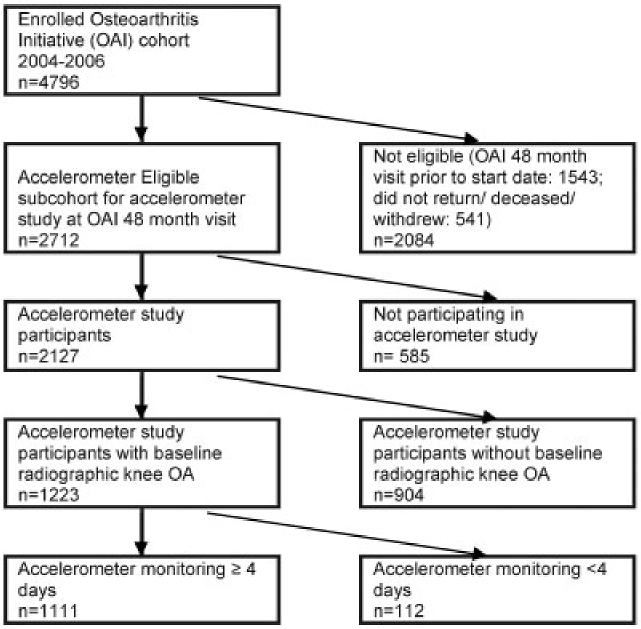

Figure 1. Flow chart of analytical sample participants from the Osteoarthritis Initiative in the present accelerometry study.

time period (e.g., in this case 1 minute), where the weights are proportional to the magnitude of measured acceleration.

Trained research personnel initialized each accelerometer and gave instructions at an in-person visit on how to position and wear the accelerometer. Participants were given uniform scripted instructions to wear the unit on a belt at the natural waistline on the right hip in line with the right axilla, from when they got up in the morning continuously until retiring at night (except during water activities) for 7 consecutive days. Participants maintained a daily log to record time spent in water and cycling activities, which may not be fully captured by accelerometry. At the end of the 7-day monitoring period, participants returned the accelerometers to the research center; data were downloaded using the manufacturer's software, and were checked for valid data recording.

Covariates. Covariates were measured at the OAI 48-month examination. Demographic factors included race/ethnicity (African American, white, or other), age, and sex. BMI was calculated as kg/m^2. If BMI information was missing at the 48-month visit, BMI from the 36-month OAI visit was used (4 participants [0.4%]). Participants were classified as normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), or obese (BMI ≥30).

Pain measures included assessments of both current and chronic knee pain. Self-reported current knee pain over the 7 previous days was measured with a 5-point Likert scale (0 = none, 1 = slight, 2 = moderate, 3 = severe, 4 = extreme) from the Western Ontario and McMaster Universities OA Index (WOMAC) (26,27) (Likert version 3.1, modified in the OAI to ask about the right and left knee symptoms separately). The WOMAC pain score range was 0–20, with a higher number representing worse symptoms. Current pain was measured as the maximum of the left and right knee WOMAC pain scores. The presence of chronic knee symptoms, which included pain, was recorded when participants responded positively when asked if they had pain, aching, or stiffness on most days of at least one month during the previous 12 months. If information on knee pain at 48 months was not available, information from the 36-month OAI visit (2 participants [0.2%]) was used.

Statistical analysis. Accelerometry data from each participant were analytically filtered to identify nonwear periods (a period when the monitor was potentially removed) during a day. Nonwear periods were defined as ≥90 minutes with no activity counts (allowing for 2 interrupted minutes with counts of <100) (28). A valid day of monitoring was defined as ≥10 wear hours in a 24-hour period (17). Although 3 days is the minimum period needed to provide a reliable estimate of physical activity (29), for this study, we conservatively included only participants who had 4 or more valid days of monitoring. These methods are consistent with accelerometry methodology used in the general population and have been validated in patients with rheumatic disease (17,28,30).

Accelerometry data were scored for the purposes of standardization. We applied intensity thresholds used by the National Cancer Institute (NCI) (17) to classify, on a minute-by-minute basis, accelerometry counts into 4 intensity levels: none to very low (0–99 counts), light (100–2,019 counts), moderate (2,020–5,998 counts), and vigorous (≥5,999 counts). Due to the low frequency of vigorous activity in this sample, only moderate-to-vigorous activity (≥2,020 counts) is reported. Moderate-to-vigorous activity increases both heart and breathing rates and is generally equivalent, at minimum, to brisk walking; light activity typically does not produce an increase in breathing or heart rate and is generally equivalent to leisurely walking (31). Total daily time (minutes) was summed for each intensity level.

In addition, we calculated daily minutes of moderate-to-vigorous physical activity occurring in bouts; a bout was defined as 10 or more consecutive minutes above the 2,020 count threshold with allowance for interruptions of 1 or 2 minutes below threshold, consistent with NCI methodology (17). Weekly totals were summed from the daily totals or estimated as 7 times the average daily total for persons with 4–6 valid days of monitoring. Each person was classified according to the 2008 Physical Activity Guidelines for Americans (28) physical activity levels, as follows: meeting recommendations (≥150 moderate-to-vigorous activity minutes [in bouts] per week), low active (1–149 moderate-to-vigorous activity minutes [in bouts] per week), or inactive (0 moderate-to-vigorous activity minutes [in bouts] per week) (32). In addition, we examined the frequency of the very active level of activity being reached (≥300 moderate-to-vigorous activity minutes [in bouts] per week), which is associated with additional health benefits, including weight loss (32). Of note, the "inactive" classification is based on the absence of bouts of moderate-to-vigorous activity (i.e., 0 minutes of moderate-to-vigorous activity that occurred in bouts lasting at least 10 minutes over 7 days). Therefore, we evaluated time spent in specific activity intensities including no to very-low-intensity activities, such as sitting and standing.

Descriptive analyses of physical activity outcomes (time that is spent in physical activity intensity categories and meets guidelines) are presented separately for men and women because of recognized sex differences in physical activity patterns (17). Group differences in percentages (noted in text by *P* values) were tested by logistic regression. For physical activity outcomes, we tested differences in group medians between men and women by nonparametric quantile regression, due to asymmetrically distributed outcomes (33). Spearman's rank correlation was used to calculate correlation coefficients between intensity outcomes. As systematic differences between the participating (n = 1,223) and nonparticipating (n = 1,456) OAI radiographic knee OA cohort could influence our findings, we performed weighted analyses as recommended by Hogan et al (34) and Robins et al (35) (results available upon request from the corresponding author). Because results were very similar and trends were identical for weighted and unweighted analyses, for simplicity, unweighted analyses are reported. All analyses were performed using SAS software, version 9.2.

RESULTS

A total of 1,223 persons ages 45–79 with radiographic knee OA (67.8% of whom had definite joint space narrowing, or the equivalent of Kellgren/Lawrence grade 3 or 4) at the baseline OAI examination consented to physical activity measurement using accelerometers at the 48-month OAI examination. Participants in this physical activity ancillary study compared to the nonparticipating OAI radiographic knee OA cohort had similar baseline age (62.0 versus 62.8 years) and BMI (29.2 versus 29.8 kg/m^2), but the group that consented had a larger proportion of participants who were male (44.9% versus 38.9%), who were white (81.0% versus 75.3%), and who had slightly less pain (mean WOMAC pain 3.5 versus 4.6).

Of the 1,223 monitored participants with radiographic knee OA at baseline, 1,111 (91.0%) had at least 4 valid days of accelerometry data; of these, 98.1% and 93.3% had at least 5 and at least 6 valid monitoring days, respectively. These 1,111 participants comprised the final study group. Characteristics of the study participants at the physical activity assessment (48-month visit) by age and sex are shown in Table 1. In the groups of patients under the age of 70 years, adults with knee OA were generally obese (40.7% of men, 48.1% of women) or overweight (45.6% of men, 31.1% of women). Among the oldest group (>70 years) obesity was less common (33.1% of men, 26.7% of women) than in the younger groups, but the proportion of participants who were overweight remained high (46.3% of men, 42.5% of women). Chronic knee symptoms were frequently reported in all groups (48.0% of men and 46.8% of women). The mean WOMAC pain score was 3.2 for both men and women.

Time spent in activities of moderate-to-vigorous–intensity that occur in episodes (i.e., bouts) lasting 10 minutes or longer is the metric on which physical activity guidelines are based. The distribution of moderate-to-vigorous daily activity in bouts per week for men and women is shown in Figure 2. Women were substantially more likely than men not to participate in any bouts of moderate-to-vigorous activity during 1 week (56.5% versus 40.1%). In addition, men generally demonstrated more moderate-to-vigorous activity than women, in amounts that meet the recommended guidelines (at least 150 moderate-to-vigorous minutes in bouts per week).

Table 1. Characteristics of the physical activity study participants with radiographic knee osteoarthritis*

Characteristic	49–59 years old		60–69 years old		≥70 years old	
	Male	Female	Male	Female	Male	Female
Participants, no.	163	146	166	214	175	247
Age, mean ± SD years	54.9 ± 2.9	54.3 ± 3.0	64.2 ± 3.0	64.9 ± 2.8	75.8 ± 3.8	75.7 ± 3.7
Race						
White	82.2	74.0	88.0	73.4	91.4	86.6
African American	15.3	22.6	9.6	24.3	6.9	11.3
Other	2.5	3.4	2.4	2.3	1.7	2.0
BMI, mean ± SD	29.4 ± 4.3	30.0 ± 5.9	29.3 ± 4.1	30.3 ± 5.4	28.6 ± 3.9	27.5 ± 4.3
Normal (18.5–24.9 kg/m^2)†	13.5	23.3	13.9	19.2	20.6	30.8
Overweight (25.0–29.9 kg/m^2)	47.9	32.9	43.4	29.9	46.3	42.5
Obese (≥30 kg/m^2)	38.7	43.8	42.8	50.9	33.1	26.7
Current knee pain, mean ± SD‡	3.3 ± 3.6	3.8 ± 4.2	2.9 ± 3.2	3.3 ± 3.8	3.3 ± 3.7	2.8 ± 3.4
Presence of chronic knee symptoms	50.3	50.7	48.2	50.5	45.7	41.3

* Except where indicated otherwise, values are the percentage of patients.
† Includes 6 participants with a body mass index (BMI) of 17.2–18.4 kg/m^2.
‡ According to the Western Ontario and McMaster Universities Osteoarthritis Index, with pain measured on a 5-point Likert scale.

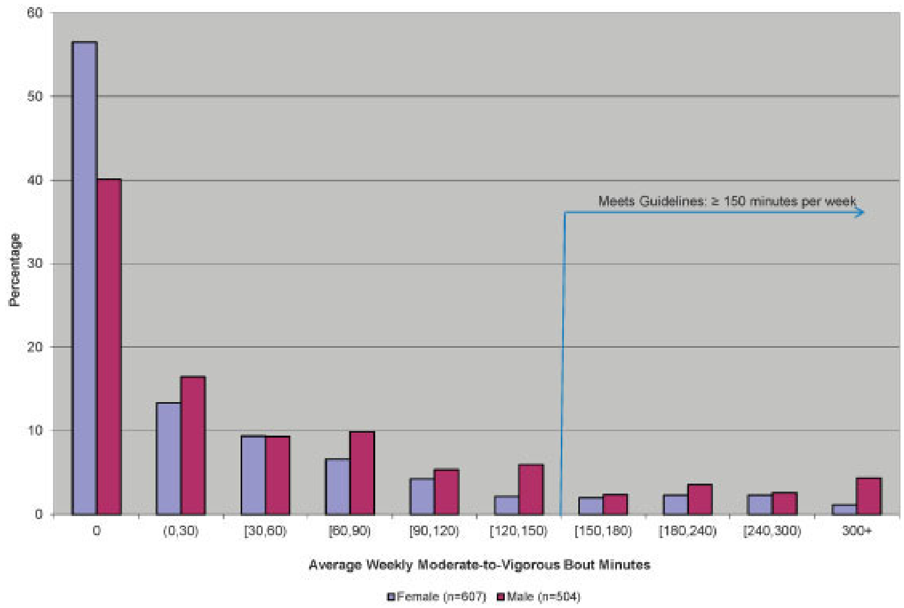

Figure 2. Distribution of moderate-to-vigorous physical activity for men and women with radiographic knee osteoarthritis who had ≥4 valid days of accelerometry monitoring.

Physical activity levels based on guidelines are summarized in Table 2. Men were significantly more likely than women to meet the recommended guidelines (12.9% versus 7.7%; $P = 0.005$) or to be in the low-activity group (47.0% versus 35.8%; $P < 0.001$). Women were significantly more likely to be classified as

Table 2. Physical activity levels based on the 2008 Physical Activity Guidelines for Americans, among men and women with radiographic knee osteoarthritis*

Characteristic (n)	Activity level, % (95% confidence interval)†			
	Inactive	Low	Active	Very active
Men				
Overall (504)	40.1 (35.8, 44.4)	47.0 (42.6, 51.4)	12.9 (10.0, 15.8)	4.4 (2.6, 6.2)
Age, years				
49–59 (163)	25.2 (18.5, 31.9)	60.1 (52.6, 67.6)	14.7 (9.3, 20.1)	6.1 (2.4, 9.8)
60–69 (166)	34.3 (27.1, 41.5)	50.6 (43.0, 58.2)	15.1 (9.7, 20.5)	4.8 (1.5, 8.1)
≥70 (175)	59.4 (52.1, 66.7)	31.4 (24.5, 38.3)	9.1 (4.8, 13.4)	2.3 (0.1, 4.5)
BMI				
Normal (18.5–24.9 kg/m^2) (81)	30.9 (20.8, 41.0)	46.9 (36.0, 57.8)	22.2 (13.1, 31.3)	8.6 (2.5, 14.7)
Overweight (25.0–29.9 kg/m^2) (231)	34.2 (28.1, 40.3)	50.7 (44.3, 57.1)	15.2 (10.6, 19.8)	4.3 (1.7, 6.9)
Obese (≥30 kg/m^2) (192)	51.0 (43.9, 58.1)	42.7 (35.7, 49.7)	6.3 (2.9, 9.7)	2.6 (0.3, 4.9)
Women				
Overall (607)	56.5 (52.6, 60.4)	35.8 (32.0, 39.6)	7.7 (5.6, 9.8)	1.2 (0.3, 2.1)
Age in years				
49–59 (146)	43.8 (35.8, 51.8)	47.3 (39.2, 55.4)	8.9 (4.3, 13.5)	2.1 (−0.2, 4.4)
60–69 (214)	49.5 (42.8, 56.2)	42.1 (35.5, 48.7)	8.4 (4.7, 12.1)	0.5 (−0.4, 1.4)
≥70 (247)	70.0 (64.3, 75.7)	23.5 (18.2, 28.8)	6.5 (3.4, 9.6)	1.2 (−0.2, 2.6)
BMI				
Normal (18.5–24.9 kg/m^2) (151)‡	39.1 (31.3, 46.9)	45.7 (37.8, 53.6)	15.2 (9.5, 20.9)	2.0 (−0.2, 4.2)
Overweight (25.0–29.9 kg/m^2) (217)	54.8 (48.2, 61.4)	35.9 (29.5, 42.3)	9.2 (5.4, 13.0)	1.4 (−0.2, 3.0)
Obese (≥30 kg/m^2) (239)	69.0 (63.1, 74.9)	29.3 (23.5, 35.1)	1.7 (0.1, 3.3)	0.4 (−0.4, 1.2)

* All data are from patients with ≥4 valid days of accelerometry monitoring.
† Inactive = no bouts of moderate-to-vigorous physical activity per week; low activity = <150 minutes per week of moderate-to-vigorous physical activity in bouts; active = meeting recommended guidelines of ≥150 minutes per week of moderate-to-vigorous physical activity in bouts; and very active = ≥300 minutes per week of moderate-to-vigorous physical activity in bouts. Bouts are defined as moderate-to-vigorous activity occurring in episodes of ≥10 minutes.
‡ Includes 6 participants with a body mass index (BMI) of 17.2–18.4 kg/m^2.

inactive than men (56.5% versus 40.1%; $P < 0.001$), accumulating no moderate-to-vigorous activity (in bouts) during the week. Significant sex differences persisted after controlling for age, BMI, current knee pain, and chronic knee symptoms (results not shown). Further analyses revealed no interaction of sex, age, or BMI with current or chronic knee symptoms in relation to physical activity levels. For both men and women, the prevalence of guidelines being met decreased with increasing BMI. The prevalence of guidelines being met was similar for groups of participants who were <70 years old (ages 49–59 12.0%, ages 60–69 11.3%), but was markedly lower after age 70 (7.6%). Sensitivity analyses conducted in participants without knee OA at baseline who also underwent accelerometry (826 with 4 or more valid days of accelerometry monitoring, of 904 participants without knee OA at baseline) also showed that guidelines were met more frequently by men (22.0%) than by women (10.8%).

Recognizing that the classification of inactivity is based solely on the absence of moderate-to-vigorous activity (in bouts), we further investigated time spent in moderate-to-vigorous activity not in bouts, as well as in lower-intensity activities. Table 3 summarizes the time spent per day in no or very-low-, light-, and moderate-to-vigorous (not in bouts)–intensity activities for men and women. Men spent significantly more time per day than women (average daily minutes 608.2 versus 585.8) in no or very-low-intensity activity, but less time in light-intensity activity (average daily minutes 262.2 versus 288.2). Men also spent significantly more time in both moderate-to-vigorous activity (not in bouts) (average daily minutes 20.7 versus 12.3) and moderate-to-vigorous activity (in bouts) (average daily minutes 9.2 versus 5.4) compared to women.

As expected, data in Table 3 also demonstrate that time spent in light and moderate-to-vigorous activity tended to decrease while no or very low activity time increased with older age and higher BMI. Time spent in no or very low activity was more strongly correlated with time spent in light activity ($r = -0.48$) than with time spent in moderate-to-vigorous activity ($r = -0.21$) or moderate-to-vigorous activity in bouts ($r = -0.11$) (results not shown). Because accelerometers were removed for water activities and may underestimate activities such as cycling, further analyses were performed on diary information (completed by 98.0% of participants) to determine the extent of these activities. Participants spent a median time of 0 minutes per day (interquartile range 0–3.6 minutes) in such activities, which indicates that nonmonitored or underestimated activity was negligible.

Table 4 shows differences in time spent in different intensities of physical activity between men and

Table 3. Time per day spent in physical activity, by intensity, among men and women with radiographic knee osteoarthritis*

Characteristic (n)	Activity intensity level†			Bouts of moderate-to-vigorous activity‡
	No to very low	Light	Moderate-to-vigorous	
Men				
Overall (504)	608.2 ± 90.9	262.2 ± 75.2	20.7 ± 20.7	9.2 ± 14.7
Age in years				
49–59 (163)	599.4 ± 96.0	278.0 ± 75.1	28.6 ± 22.7	11.6 ± 15.6
60–69 (166)	601.6 ± 89.9	275.5 ± 66.4	22.2 ± 18.9	10.1 ±13.7
≥70 (175)	622.7 ± 85.4	234.9 ± 75.8	11.9 ± 16.7	6.0 ± 14.2
BMI				
Normal (18.5–24.9 kg/m^2) (81)	604.7 ± 93.3	271.1 ± 81.8	25.6 ± 25.4	13.0 ± 19.0
Overweight (25.0–29.9 kg/m^2) (231)	603.2 ± 85.9	268.9 ± 69.9	22.9 ± 19.7	10.5 ± 13.5
Obese (≥30 kg/m^2) (192)	615.8 ± 95.5	250.4 ± 77.3	16.0 ± 18.7	6.0 ± 13.3
Women				
Overall (607)	585.8 ± 95.6	288.2 ± 80.6	12.3 ± 14.3	5.4 ± 10.9
Age in years				
49–59 (146)	570.1 ± 102.7	319.8 ± 82.6	19.8 ± 14.8	7.1 ± 11.5
60–69 (214)	579.5 ± 92.1	297.5 ± 73.5	11.9 ± 11.7	5.6 ± 9.5
≥70 (247)	600.4 ± 92.6	261.5 ± 76.9	8.3 ± 14.4	4.2 ± 11.6
BMI				
Normal (18.5–24.9 kg/m^2) (151)§	590.1 ± 93.0	282.8 ± 68.2	17.1 ± 17.8	9.4 ± 14.8
Overweight (25.0–29.9 kg/m^2) (217)	587.8 ± 95.7	292.0 ± 81.9	12.5 ± 14.5	5.7 ± 10.9
Obese (≥30 kg/m^2) (239)	581.1 ± 97.4	288.2 ± 86.5	9.0 ± 10.3	2.5 ± 6.3

* Values are the mean ± SD daily activity minutes. All patients had ≥4 valid days of accelerometry monitoring.
† No to very low activity = accelerometry counts of 0–99/minute; light activity = accelerometry counts of 100–2,019/minute; moderate-to-vigorous activity = accelerometry counts of ≥2,020/minute not restricted to bouts of activity.
‡ Bouts of ≥10 consecutive minutes participating in activity at the ≥2,020 count threshold.
§ Includes 6 participants with body mass index (BMI) of 17.2–18.4 kg/m^2.

Table 4. Median differences between men and women in physical activity minutes per day by activity intensity level, among adults with radiographic knee osteoarthritis*

Characteristic (n)	Activity intensity level, difference in minutes/day (95% confidence interval)†			Bouts of moderate-to-vigorous activity‡
	No to very low	Light	Moderate-to-vigorous	
Overall (1,111)	28.9 (16.1, 41.6)§	−33.4 (−42.4, −24.4)§	4.6 (3.2, 6.1)§	1.1 (0.6, 1.5)§
Age, years				
49–59 (309)	18.7 (−3.8, 41.3)	−36.4 (−58.4, −14.4)§	6.3 (1.5, 11.2)§	3.6 (2.9, 4.4)§
60–69 (380)	35.2 (8.4, 61.9)§	−21.7 (−35.5, −8.0)§	9.8 (6.2, 13.4)§	1.9 (1.2, 2.6)§
≥70 (422)	31.0 (13.8, 48.2)§	−29.2 (−53.1, −5.3)§	2.5 (1.2, 3.8)§	0.5 (−0.2, 1.1)
BMI				
Normal (18.5–24.9 kg/m^2) (232)¶	23.1 (−2.9, 49.0)	−24.1 (−49.1, 0.9)	4.4 (0.6, 8.2)§	0.6 (0.1, 1.0)§
Overweight (25.0–29.9 kg/m^2) (448)	18.8 (−0.3, 38.0)	−30.3 (−41.4, −19.2)§	7.4 (4.7, 10.0)§	1.6 (1.2, 2.1)§
Obese (≥30 kg/m^2) (431)	40.7 (19.3, 62.0)§	−37.7 (−54.1, −21.4)§	1.8 (0.1, 3.6)§	0.6 (−0.1, 1.3)

* Differences between male and female participants with ≥4 valid days of accelerometry monitoring were adjusted for age (except for the analyses with age as the variable), race, body mass index (BMI) (except for the analyses with BMI as the variable), current pain severity, and chronic knee symptoms. Values represent the differences in minutes among men in relation to women (i.e., positive values indicate more minutes among men than women, and negative values indicate fewer minutes among men than women). Ninety-five percent confidence intervals were estimated from quantile regression.
† No to very low activity = accelerometry counts of 0–99/minute; light activity = accelerometry counts of 100–2,019/minute; moderate-to-vigorous activity = accelerometry counts of ≥2,020/minute not restricted to bouts of activity.
‡ Bouts of ≥10 consecutive minutes participating in activity at the ≥2,020 count threshold.
§ $P < 0.05$.
¶ Includes 6 participants with BMI of 17.2–18.4 kg/m^2.

women, after adjustment for factors that may affect physical activity level (e.g., BMI, pain as assessed by WOMAC, chronic knee symptoms, and demographic characteristics). Men with knee OA spent significantly more time in no to very low activity and moderate-to-vigorous activity (average daily minutes 28.9 and 4.6, respectively) than women. However, women spent more time in light activity (average daily minutes 33.4) than men. Further analyses were performed to examine differences between men and women within age and BMI weight groups. Across all age groups and BMI categories, women spent significantly more time in light activity while men spent more time in moderate-to-vigorous activity. In addition, men spent more time than women in no or very-low-intensity activities; those differences were statistically significant or achieved borderline significance. Sensitivity analyses with further controlling for radiographic OA severity from the baseline visit (results not shown) yielded almost identical results.

DISCUSSION

These findings demonstrate, among adults with radiographic knee OA, the prevalence of the Physical Activity Guidelines for Americans aerobic recommendations being met and time spent in different physical activity intensity levels using objectively measured accelerometry data. Despite substantial evidence showing that health benefits are related to physical activity, participants who had knee OA engaged in little physical activity. Fewer than 1 in 7 men and 1 in 12 women with knee OA accumulated sufficient physical activity to meet the guidelines. More than one-third of men and more than half of women were considered completely inactive, performing no sustained moderate-to-vigorous activity that lasted 10 minutes or more. Although men engaged in significantly more daily moderate-to-vigorous activity (measured in minutes) compared to women, they also accrued significantly more time engaged in no to very-low-intensity activities than women. These findings emphasize the urgent need for widespread dissemination of public health interventions to reduce the sedentary lifestyle of the 27 million adults who have knee OA.

This study, based on objectively measured physical activity using accelerometers, showed that 12.9% of men and 7.7% of women with radiographic knee OA met the current recommended guidelines. This finding indicates that the vast majority of adults with knee OA are not participating in guideline-recommended activity levels to benefit overall health (e.g., reduction in mortality from cardiovascular disease). National data on self-reported physical activity from the 2002 National Health Interview Survey (NHIS) revealed that 30% of adults over the age of 18 years with self-reported doctor-diagnosed arthritis met physical activity recommendations (16). Self-reported physical activity information from the 2000 and 2001 Behaviors Risk Factor Surveillance Surveys (BRFSS) of US states showed that 22–40% of adults over the age of 45 with self-reported doctor-diagnosed arthritis met recommended levels (36,37). One clinical study that objectively assessed physical activity in 259 participants using accelerometers found that 30% of adults ages 35–65 years with confirmed early knee OA accumulated at least 30 minutes/day of moderate-to-vigorous activity. However, that study did not assess moderate-to-vigorous activity in bouts (the metric used in public health recommendations), which comprises less than one-half of overall moderate-to-vigorous activity in adults over age 40 (17).

Our results applying the current guidelines (≥150 minutes of moderate-to-vigorous activity, in bouts, per week) to objective accelerometry assessments from a cohort of participants with knee OA indicated that a much lower proportion met physical activity recommendations than was described in previous reports concerning these arthritis populations. Consistent with these findings, a sensitivity analysis using the OAI accelerometry sample of patients who did not have baseline knee OA showed that a lower proportion of participants met current guidelines (15.7%), based on objective assessment, than were shown in the 2002 NHIS subjects without arthritis (38% of whom met recommendations), as estimated using self-reported physical activity (16).

There may be several reasons why our prevalence estimates of physical activity recommendations being met among adults with arthritis are lower than previous prevalence estimates. First, the arguably strongest contributor to differences in estimates is that these previous population-based estimates used self-reports of physical activity to assess whether physical activity guidelines were met, in contrast to the present study, which was based on objectively measured physical activity. Self-reports of physical activity have been shown to overestimate objectively measured physical activity in the general population, particularly in older, obese individuals (38,39).

Second, prior to the 2008 guidelines, criteria for meeting physical activity recommendations were stricter, based on engaging in 30 minutes or more per day of moderate-intensity activity (in bouts) on ≥5 days of the week (5 × 30) or 20 minutes of vigorous-intensity activity on ≥3 days per week (3 × 20) (40). Individuals who did some moderate-intensity or vigorous-intensity activity, but not enough to meet either the 5 × 30 or the 3 × 20 criteria, would be classified as not meeting physical activity recommendations. In practice, this issue likely has little effect, since we summed all moderate- and vigorous-intensity activity before applying the guideline recommendation of 150 minutes/week and still found very low rates of recommendations being met.

Third, the case definition of arthritis used in national health surveys such as the NHIS and BRFSS includes persons with OA, rheumatoid arthritis, lupus, fibromyalgia, and gout, while our study used a strict case definition of radiographic knee OA. It is not known how much the prevalence of meeting physical activity recommendations varies among different types of arthritis. However, OA is the most common type of arthritis in the US and would be the predominant type of arthritis represented in those national samples.

Last, the NHIS national health survey included adults as young as 18 years old who had arthritis, while our study evaluated participants ages 49 and older, who may be less active than younger adults. However, 30% of that NHIS arthritis population met physical activity guidelines, which is comparable to the 22–40% of the BRFSS arthritis population of adults ages 45 and older meeting guidelines, so it is likely that differences due to a wider age span are small.

A substantial proportion of men and women (40.1% and 56.5%, respectively) were classified as inactive, having no bouts of moderate-to-vigorous activity lasting 10 minutes or longer. These results are consistent with the 2002 NHIS findings, which classified 40.0% of men and 45.8% of women with arthritis as inactive, based on their self-reported activity (16). Our study confirms these previous estimates, using an objective measure of activity. Although no minimum dose of moderate-to-vigorous activity resulting in health benefits has been identified specifically for adults with arthritis, transitioning from inactive to low activity classification (1–149 moderate-to-vigorous minutes [in bouts] per week) has been shown to have substantial benefits, including reduced mortality and risk for incident coronary heart disease, hypertension, and diabetes. For example, as little as 60–90 minutes per week of moderate-to-vigorous physical activity reduces the risk of premature mortality by ~25% (8). This health benefit, coupled with the fact that moderate, low-impact exercise has been proven safe and effective for adults with arthritis, affirms the Healthy People 2020 recommendation that adults with OA should be counseled to be as physically active as possible (i.e., avoid inactivity), even if they may never intend to engage in sufficient activity to meet recommendations (41). Indeed, avoiding time spent in no to very-low-intensity activity may be the first realistic goal for those with knee pain/mobility issues.

Studies of physical activity have largely concentrated on time spent in moderate-to-vigorous activity. However, that focus neglects the potential health benefits of time spent in light-intensity activities compared to no to very-low-intensity activity, such as sitting. Physiologically, uninterrupted inactivity suppresses skeletal muscle lipoprotein lipase activity and reduces glucose uptake (42,43). Time spent in no to very low activity is associated with larger waist circumference, with poor 2-hour plasma glucose levels and triglyceride profiles, and with increased metabolic risk scores (44,45). A sedentary lifestyle can have adverse effects even among otherwise physically active people. In >4,000 adults from the Australian Diabetes, Obesity, and Lifestyle study, longer time spent watching television was significantly associated with larger waist circumference and higher systolic blood pressure and 2-hour plasma glucose, even among active adults who reported activity levels compatible with guidelines (45).

We found a negative correlation between no to very-low-intensity activity time and light activity time in this cohort with knee OA ($r = -0.48$), which was stronger than the correlation of no to very-low-intensity activity time with moderate-to-vigorous–intensity activity time. Trading sitting activities for light-intensity activities, such as gardening or leisurely walking, may be an intermediate step toward change in undesirable behaviors, mediated through improved self-efficacy. This strategy may be particularly helpful for adults with arthritis who fear that their symptoms will become worse through increased activity levels. Once they have been successful at replacing time spent in no to very-low-intensity activities with light activity, counseling efforts can be targeted toward increasing the intensity of activity. In addition, any movement beyond lying or sitting contributes to total daily energy expenditure; increased activity when coupled with dietary caloric restriction may produce weight loss. These potential benefits motivate the promotion of light- to moderate-intensity activities in persons with knee OA as a feasible approach to reducing no to very low activity time and possibly improving health outcomes.

This study had substantial strengths, including the large sample size, the objective accelerometry assessment of physical activity, radiographic verification of knee OA, and the diversity in age and sex of this OA cohort. However, there are also limitations that should be acknowledged. Accelerometry does not provide qualitative information on context of the physical activity (e.g., household, transportation, outdoor location); this information might be helpful to target interventions. While accelerometry information could be used to assess the aerobic component of the physical activity guideline recommendation, it is not known if that activity was accomplished using low-impact activities (which are advised for people with arthritis), nor could the muscle-strengthening component of the recommendation be assessed. The accelerometry model used in this study cannot capture water activities and may underestimate upper body movement or vertical acceleration/deceleration activities, such as cycling. Diary information indicated that the median time subjects spent in water and cycling activities was 0 minutes/day, so the potential underestimate is negligible. It is possible that wearing an accelerometer may have made individuals more aware of activity, providing a stimulus to participate in physical activity. To minimize such effects, the accelerometer provided no feedback to the participant on monitored activity. If participation rates were inflated due to the presence of the monitor, the true day-to-day physical activity levels would be even lower than those observed.

Radiographic data on joint damage were available only from baseline, 4 years prior to the current study. Sensitivity analyses that controlled for baseline radiographic status showed similar statistical differences to the reported findings. Additionally, it should be recognized that outside of the OAI physical activity ancillary study, populations are likely to have greater proportions of female or African American patients, as well as higher levels of baseline pain. Because these differential characteristics are associated with lower levels of physical activity, our findings represent a conservative upper bound on physical activity levels for adults with knee OA. However, sensitivity analyses that accounted for these differential characteristics among OAI participants not assessed by accelerometry yielded similar estimates and identical trends, suggesting that any bias in our findings is small.

We conclude that, despite the substantial health benefits related to physical activity, adults with radiographic knee OA are particularly inactive. Only 12.9% of men and 7.7% of women met public health physical activity guidelines, as assessed using an objective measure; these estimates were substantially lower than previous reports based on self-reported activity in arthritis populations. Although men engaged in significantly more moderate-to-vigorous–intensity activity compared to women, they also spent significantly more time in no to very-low-intensity activity. A substantial proportion of men and women (40.1% and 56.5%, respectively) were classified as inactive, participating in no episodes of moderate-to-vigorous activity lasting >10 minutes. These findings demonstrate the critical need to intensify public health efforts to increase physical activity and reduce sedentary time in both men and women with knee OA.

AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Dr. Dunlop had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition of data. Dunlop, Song, Semanik, Bathon, Eaton, Hochberg, Jackson, Kwoh, Mysiw, Nevitt.

Analysis and interpretation of data. Dunlop, Song, Semanik, Chang, Sharma, Bathon, Mysiw, Hootman.

ROLE OF THE STUDY SPONSOR

The private funders of the OAI did not participate in data analyses or data interpretation and did not review or approve the manuscript.

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