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Potential Functional Benefit From Light Intensity Physical Activity in Knee Osteoarthritis

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Abstract

Introduction—Knee pain may preclude participation in higher intensity physical activity in people with knee osteoarthritis and benefits of light activity are unclear. The effect of replacing sedentary time with light intensity activity on incident functional limitation 2 years later was investigated.

Methods—Included were people with or at high risk of knee osteoarthritis without baseline functional limitation using data from the Osteoarthritis Initiative collected between August 2008 and July 2010. Data was analyzed between May 2016 and August 2016 for time in sedentary, light, and moderate to vigorous physical activity from accelerometer monitoring. Incident functional limitation was defined as (1) slow gait speed <1.0 meters/sec during a 20-meter walk, (2) Western Ontario and McMasters University Osteoarthritis Index physical function >28, or (3) Short Form 12 Physical Component scale <40.

Results—Inclusion criteria was met by 1,873 people (mean age=65.0 [SD=9.0] years, mean BMI=28.4 [SD=4.7] kg/m^2). Replacing 60 minutes/day of sedentary time with 60 minutes/day of light activity was associated with a 17% reduced risk for incident slow gait speed 2 years later (Hazard Ratio=0.83, 95% CI=0.70, 0.99) after adjustment. Approximately 5 minutes/day of moderate to vigorous physical activity would be necessary to receive the equivalent benefit of 60 minutes/day of light activity. Effects in secondary patient-reported outcomes did not reach statistical significance.

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All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years, and no other relationships or activities that could appear to have influenced the submitted work.

Conclusions—Replacing sedentary time with light activity may reduce the risk of performance-based functional limitation. As expected, moderate to vigorous physical activity rather than light provided stronger risk reduction. When moderate to vigorous physical activity is not an option, pursuing light activity may be a beneficial alternative to being sedentary.

INTRODUCTION

Knee osteoarthritis (OA) is the 11th highest contributor to global disability[1] and the leading cause of functional limitation in older adults.[2,3] Because knee OA has no known cure, the prevention of functional limitation is paramount. Engaging in physical activity is known to protect against functional limitation. For instance, structured exercise programs, such as resistance training[4] and aerobic walking,[5] and unstructured physical activity, such as increasing steps/day[6] protect against functional limitation among people with knee OA. Less is known about the potential beneficial effects of specific intensities of physical activity on function in people with knee OA.

First, little empirical evidence exists to support whether light intensity activity benefits physical function for people with knee OA. This is a major gap because people with knee OA often have knee pain that precludes higher intensity activity, such as aerobic walking or hiking, and may subsequently need to rely on light intensity activities, such as light household cleaning or gardening, as sources of physical activity. Second, presuming light intensity activity benefits people with knee OA, it is unclear how much moderate to vigorous intensity physical activity (MVPA) may be needed to equal the benefit of light activity. Understanding these associations are important to inform patients and health providers of the potential implications of participating in different intensities of physical activity, (i.e., gauge the “return on the investment” of being physically active).

The purpose of this study is to investigate the protective association of replacing sedentary time with light intensity physical activity on the development of functional limitation 2 years later in people with or at high risk of knee OA. Also examined is how much light activity was needed to equal the benefit of MVPA in instances where both were associated with study outcomes. An isotemporal substitution model was employed to estimate the relative benefit of replacing a fixed time of sedentary activity with light intensity or with MVPA, a methodology previously employed in physical activity studies.[7,8]

METHODS

Study Sample

The Osteoarthritis Initiative (OAI) is a longitudinal cohort study of the risk factors and natural history of OA. Men and women aged 45 to 79 years were recruited from four clinical sites: Baltimore, Maryland; Pittsburgh, Pennsylvania; Pawtucket, Rhode Island; and Columbus, Ohio. OAI enrolled participants with or at elevated risk of developing symptomatic knee OA. Complete inclusion and exclusion criteria and study rationale can be found at www.oai.ucsf.edu/datarelease/About.asp. Participants included in the study were assessed annually. IRB approval was obtained from all OAI sites.

A subgroup of 2,098 OAI participants free of functional limitation participated in a study that objectively measured physical activity at the 48-month clinic visit from August 2008 to July 2010, which represents the study's baseline.[9] For the present analysis conducted from May 2016 to August 2016, OAI publically released clinical data were used from this subgroup collected from the baseline (OAI 48-month), 2-year (OAI 72-month), and 4-year (OAI 96-month) followup visits. Figure 1 provides a summary of the number of accelerometer records at each stage of study. Of the 1,954 OAI participants who wore the accelerometer for >4 valid days at baseline, 5% (n=81) were lost to follow-up, resulting in an analytic sample size of n=1,873. In general, participants included in the analytic sample (n=1,873) were more likely to be white, had at least a college degree, and had no depressive symptoms compared with those who were lost to follow-up (n=81) not included in the analysis (Appendix Table 1).

Measures

Physical activity was monitored at baseline and the 2-year follow-up visits using an ActiGraph GT1M accelerometer. Briefly, the Actigraph GT1M is a small uniaxial accelerometer that measures acceleration and deceleration along a vertical axis,[10] and is a valid measure of energy expenditure[11] with high test–retest reliability when measured over >4 days.[12] Study subjects were asked to continuously wear the accelerometer for 7 consecutive days from getting up the morning until going to bed in the evening, with the exception of water activities. Procedures for the placement, instructions, and data management for accelerometers in the OAI have been previously described.[9]

Accelerometer data were processed using established validated methodologies.[13,14] Accelerometer data were first filtered to identify non-wear periods, (i.e., when the study subject may have removed the monitor), during a day. Potential wear time was first calculated from daily log diaries. Next non-wear was subtracted from potential diary wear time, which was defined as >90 consecutive minutes with activity counts=0 (allowing for 2 consecutive interrupted minutes with activity counts <100), consistent with previously published methods.[9,13] Included were participants who had >4 valid days of wear time (i.e., >10 hours in a 24-hour period) in order to provide reliable estimates of physical activity.[15]

National Cancer Institute intensity thresholds were applied to classify accelerometer counts into three intensity levels: sedentary (0 to 99 counts), light (100 to 2019 counts), and moderate to vigorous (>2,020 counts) on a minute-by-minute basis.[15] Total time in minutes/day was summed for each intensity level of physical activity.

The functional limitation was defined using both performance-based and patient-reported measures because both provide distinct information about the underlying construct of physical function.[16] The primary outcome was incident functional limitation over 2 years for each study outcome among study participants free of functional limitation at baseline for the baseline to 2-year interval. Similarly, those free of functional limitation at the 2-year visit contributed outcome data from the 2- to 4-year interval. Baseline data for 51 participants came from OAI 72-month visit as they did not have data from OAI 48-month visit.

Functional limitation was defined as walking with a gait speed <1.0 meters/second, (i.e., a slow gait speed). Walking below this speed is a risk factor for hospitalization and mortality in older adults.[17,18] Gait speed was determined from the average of two trials at a usual pace >20 meters.

The Western Ontario and McMasters University Osteoarthritis Index (WOMAC) physical function subscale (0–68, higher scores are worse) was used as a patient-reported measure of physical function.[19,20] The physical function subscale includes 17 items measuring difficulty with mobility, activities of daily living, and heavy and light domestic duties. Functional limitation was defined as a score of >28 using the WOMAC.[21,22] Those with a score of >28 report having at least slight to moderate difficulty in all 17 tasks from the WOMAC physical function scale, or severe to extreme difficulty in 7 to 9 tasks. OAI study participants rated each knee separately and worse knee was used in analyses.

The Short Form 12 (SF-12) Physical Component Scale is a global measure of patient-reported physical function.[23,24] Scores of the SF-12 range from 0 to 100 with lower scores being worse, and are standardized to a population mean of 50 with a 10-point SD. Function limitation was defined as a score <40, representing one SD below the population average.

Both gait speed and WOMAC physical function have high test–retest reliability in people with knee OA[19,25] and older adults.[26] The SF-12 has high test–retest reliability in the general U.S. population.[23]

The following baseline factors were considered as potential confounders based on their association with physical activity and functional limitation[21,27,28]: age, sex, race (white, African American, other), education (high school graduate or less versus some college or more), and health factors including BMI, comorbidity, depressive symptoms, lower body pain, and the presence of radiographic knee OA. Knee pain in the last 30 days (0–100) was reported using a Visual Analogue Scale. Self-reported comorbidities were based on the modified Charlson comorbidity index[29] (>1 vs none). Depressive symptoms were measured using the Center for Epidemiologic Studies Depression Scale[30] (>16 as having major depressive symptoms vs <16 as not having major depressive symptoms). Lower body pain includes symptoms in the hips, ankles, or feet (present versus absent). Radiographic evidence of osteoarthritis (ROA) was identified by a Kellgren–Lawrence grade score of >2 in one or both knees assessed from “fixed-flexion” knee radiography protocol at or before the baseline clinic visit.[31]

Statistical Analysis

Descriptive statistics of time spent in different intensities of physical activity and the proportion of the sample with incident functional limitation are presented. An isotemporal substitution model was employed to evaluate the effect of replacing sedentary time with time spent in light activity.[7] If the observed effect met statistical significance, what duration of time replacing sedentary time with MVPA approximated the same effect on functional limitation as replacing sedentary time for light activity was evaluated. The “substitution effect” is examined by replacing activity from one intensity category with an equal amount

of time in a different category, while also adjusting for total daily wear time and the independent effects of other activities simultaneously.

Discrete time hazards models were used for the incidence of functional limitation, which accounted for multiple interval records from the same participant, (i.e., those who contributed data from the baseline to 2-year and 2- to 4-year intervals).[32] This method estimated the discrete hazard rate, which is the probability of developing functional limitation in each subsequent 2-year interval given the participant's functional limitation free status at the previous interval. Hazard ratios (HRs) and 95% CIs for developing functional limitation were adjusted for potential confounders from the starting point of each interval. HRs <1.0 indicate a protective effect of replacing light activity or MVPA for the same amount of sedentary time.

To examine the consistency of replacing light and MVPA for sedentary time with incident functional limitation by OA status, all analyses were repeated by restricting the sample to those with knee ROA followed by further restricting to those with symptomatic knee ROA. The standard definition for symptomatic knee OA from the OAI was applied, which includes both ROA, and the presence of symptoms, defined as pain, aching, or stiffness on most days of a month during the previous year.

RESULTS

The mean (SD) age and BMI of the current study sample was 65.0 (SD=9.0) years and 28.4 (SD=4.7) kg/m^2, respectively. A majority of the participants were women (54.7%) and white (84%). Table 1 summarizes participant characteristics of the analytic sample.

Of the 1,663 participants without slow gait speed at baseline (>1.0 meters/second), 127 developed a slow gait speed over the follow-up. In general, those with an incident slow gait speed spent more time being sedentary and less time in light activity and MVPA compared with those without incident slow gait speed (Table 2).

Replacing 60 minutes/day of sedentary time with 60 minutes/day of light intensity physical activity reduced the risk of developing a slow gait speed by 17% after adjustment for potential confounders (Adjusted HR=0.83, 95% CI=0.70, 0.99). Reducing the replacement to 30 minutes/day attenuated the protective effect to 9% (Figure 2). One would have to replace 5 minutes/day of sedentary time with 5 minutes/day of MVPA to receive the equivalent benefit of replacing 60 minutes/day of light for sedentary time, (i.e., a 17% reduction in risk of developing a slow gait speed).

Of the 1,769 without functional limitation at baseline as measured by WOMAC, 195 developed functional limitation over the follow-up. Those who developed functional limitation spent similar time being sedentary and in light activity, and less time in MVPA compared with those without incident functional limitation (Table 2).

Replacing 60 minutes/day of sedentary time with 60 minutes/day with light activity was associated with a 3% protective effect from incident knee-specific functional limitation as measured by WOMAC, which did not meet statistical significance after adjustment for

potential confounders (Adjusted HR=0.97, 95% CI=0.96, 1.11). Replacing 30 minutes/day was not associated with a protective effect as measured by WOMAC (Figure 2).

Of the 1,557 free of functional limitation at baseline as measured by SF-12, 278 developed functional limitation over the follow-up. Those who developed functional limitation spent similar time being sedentary and in light activity, and less time in MVPA compared with those without incident functional limitation (Table 2). Replacing 60 and 30 minutes/day of sedentary time with light activity was not associated with functional limitation (Adjusted HR=1.02, 95% CI=0.92, 1.14, 1.01, 95% CI=0.96, 1.07, respectively; Figure 2).

Similar results for all the study outcomes were found when restricting the sample to those with ROA (Appendix Figure 1) and symptomatic knee OA (Appendix Figure 2). Replacing 60 minutes/day of sedentary time with light activity was associated with a 15% protective effect from slow gait speed for the sample with ROA, and an 11% protective effect from slow gait speed for the sample with symptomatic knee OA. However, these effects did not reach statistical significance when adjusted for potential confounders.

DISCUSSION

Replacing sedentary time with light intensity activity had a modest but statistically significant reduction in risk of developing performance-based functional limitation 2 years later in this large prospective cohort study of people with or at elevated risk for knee OA. Light intensity activity was not protective for patient-reported functional limitation. About 60 minutes/day of light activity was equivalent to about 5 minutes/day of MVPA to convey the same 17% reduced risk for slow walking. Replacing sedentary time with light activity remained protective, but did not meet statistical significance when restricted to people with knee ROA or symptomatic knee OA because of smaller sample sizes. Thus, light intensity physical activity may be beneficial to preserve the performance of function regardless of OA status for people with or at risk of knee OA.

Light intensity physical activity was protective against incident functional limitation as defined by slow walking, which is consistent with previous work with outcomes in disability[33] and mortality.[34] This finding is important because light activity may be the only intensity of physical activity available to people with knee OA who find higher intensity activities to be difficult due to pain. Importantly, this protective effect was significant to reduce the development of slow gait speed, which is a known risk factor for death,[18] persistent lower extremity limitation, and hospitalization in older adults.[17]

Previously, it was unclear how much light activity would equate to the benefits of MVPA. As expected, stronger protective effects of MVPA rather than light intensity physical activity was found with incident performance-based functional limitation. An average of 60 minutes/day of light activity is needed to convey the same benefit as 5 minutes/day of MVPA to prevent slow walking. A possible reason why replacing MVPA is more efficient than light intensity is because MVPA necessitates greater lower body muscle strength than light intensity activity.[35] In fact, MVPA taxes all body systems, such as the cardiovascular,

neural, and somatosensory components greater than light intensity activity likely preserving the ability of these underlying systems to support physical function.

Physical activity was more protective against developing functional limitation assessed by performance than for patient-reported outcomes, (i.e., WOMAC or SF-12). This may have occurred for several reasons. First, it is possible that those who were more active simply walked more,[36–38] and consequently there was a strong association between physical activity and preservation of gait speed. Second, the patient-reported outcomes included a wide variety of activities in addition to walking, which may capture variability of response and contribute to less precision. Lastly, estimates of physical function obtained from patient reported outcomes are known to differ from that obtained from performance-based instruments.[16]

Limitations

There are limitations to the study to acknowledge. The accelerometer the OAI employed recorded movement in units of activity counts, thus the exact types of activities employed to attain light activity and MVPA cannot be reported. In addition, there is a possibility of confounding because of unmeasured factors. Hence, the results should be interpreted with caution. Ideally a clinical trial with randomization should be conducted to more definitively establish the protective association between light intensity physical activity and future functional limitation. However, until a clinical trial is conducted, the study provides preliminary guidance with the magnitude of functional benefit that may occur with participation in light and MVPA. Three outcome definitions of limitation were employed, however because there is no gold standard definition for functional limitation, the outcomes do not represent an exhaustive list of such limitation. Lastly, the study had smaller sample sizes for analyses restricted to ROA and symptomatic OA, hence there was less power to show statistical significance. The study has valuable strengths including the analysis of longitudinal prospective data and objective accelerometer physical activity monitoring. Importantly, the relative benefit of replacing light activity for sedentary time on functional limitation in knee OA was investigated; a paucity of studies currently exist to show the benefit of light intensity physical activity in knee OA.

The study findings support recommendations by health professionals for light physical activity in addition to MVPA for people with or at high risk of knee OA. Advice to increase moderate activity often focuses on brisk walking. But, this intensity may be difficult for people with knee pain or other lower body pain. These results indicate replacing sedentary time with enjoyable light activities, such as taking a casual stroll, could also be beneficial. Examples of other enjoyable and practical types of light intensity activities may include grocery shopping with a cart, light effort household cleaning, and watering the lawn or garden.

CONCLUSIONS

In summary, replacing sedentary time with light intensity activity may reduce the risk of incident performance-based functional limitation 2 years later in people with or at high risk of knee OA. Replacing an hour per day of sedentary time with light activity equates the

same benefit of replacing 5 minutes/day of sedentary time with MVPA. Health professionals may consider recommending activity to people with knee OA, even if only light activity is possible, in order to minimize the risk of developing future functional limitation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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DKW and DD were involved in conception and design of the study and in analysis and interpretation of the data. DD, JL, and JS were involved in collection of data. All authors were involved in the interpretation of data. DKW drafted the manuscript. All authors were involved in revision and final approval of the manuscript. All authors had full access to all of the data in the study. DKW and DD are the guarantors.

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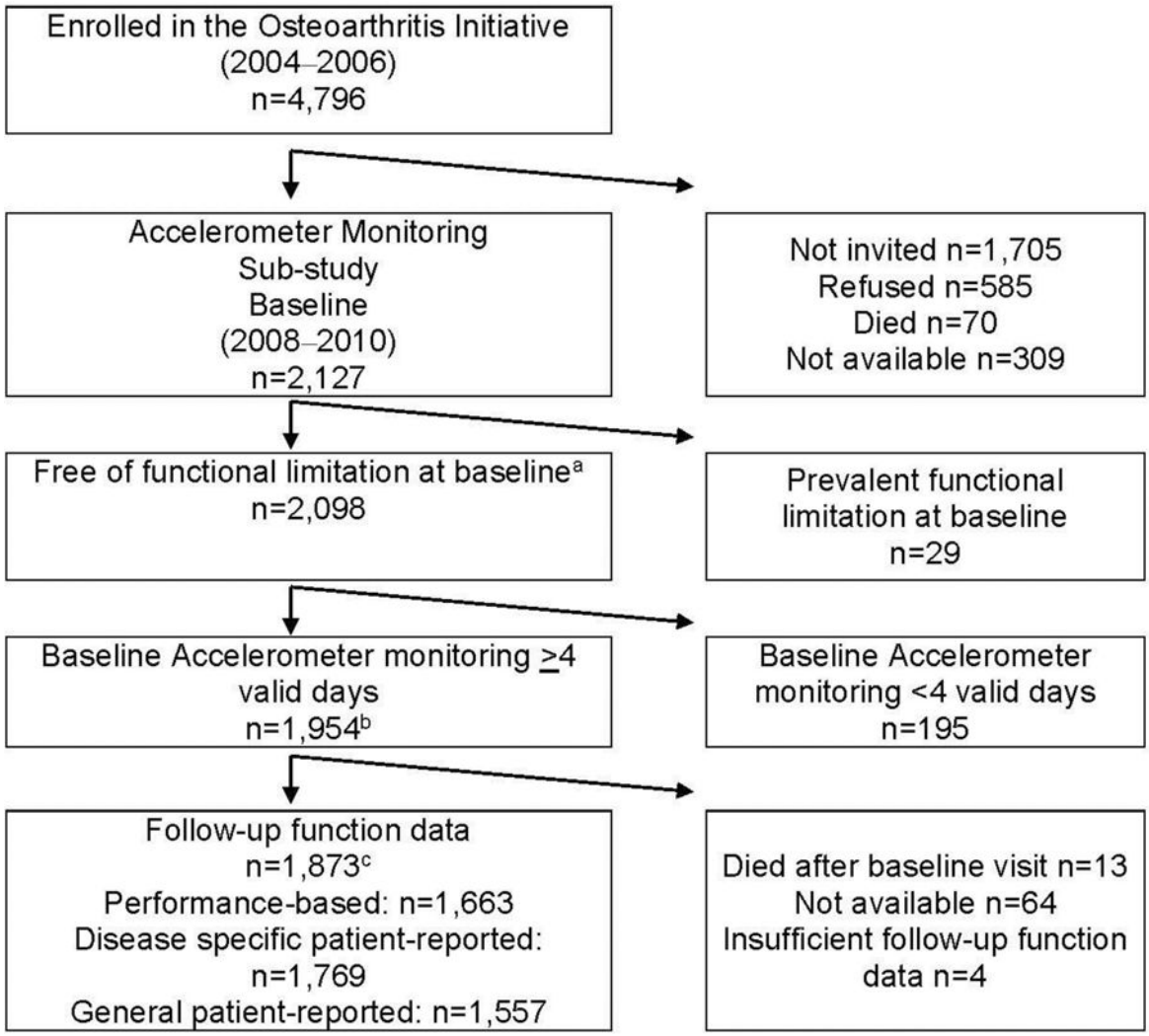

Figure 1.

Flow chart for sample size.

[a]Functional limitation is defined as a gait speed <1 meter/second, WOMAC <28, or SF-12 <40.

[b]For n=51 participants baseline monitoring occurred at the OAI 72-month visit.

[c]Functional outcomes included those taken at the 72- and/or 96-month OAI visits.

WOMAC, Western Ontario and McMasters University Osteoarthritis Index; SF-12, 12-item Short Form health survey; OAI, Osteoarthritis Initiative

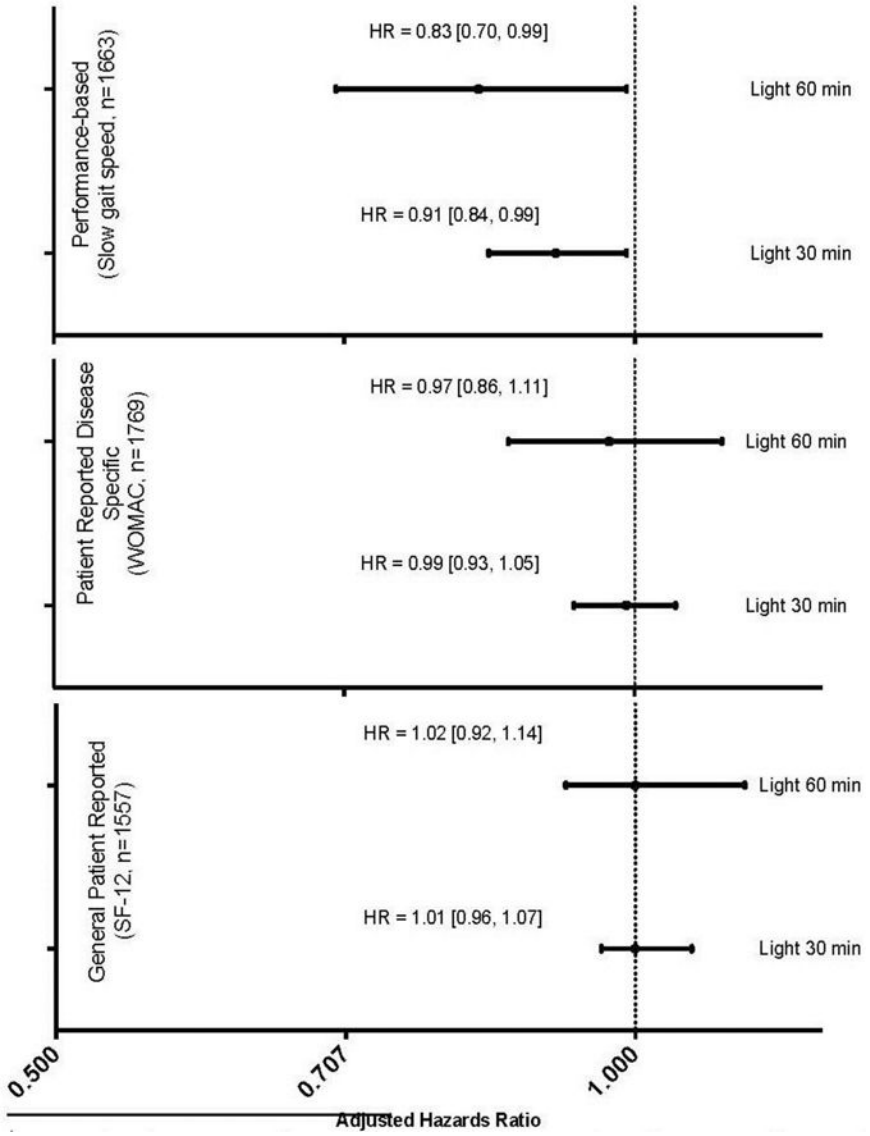

Figure 2.

Adjusted[a] hazard's ratio of replacing sedentary time for the same fixed time in light intensity physical activity with incident functional limitation. Time is defined as average minutes/day.

[a]Hazard ratios were adjusted for age, sex, race, education, BMI, knee pain in the last 30 days, comorbidities, depressive symptoms, lower body pain in the hips, ankles, or feet, and radiographic evidence of OA.

HR, Hazards Ratio; WOMAC, Western Ontario and McMasters University Osteoarthritis Index Physical Function Scale; SF-12, 12-item Short Form health survey

Table 1

Participant Characteristics at the Study Baseline Visit

Characteristics	Entire sample included in analysis n=1,873	Sample with ROA included in analysis n=1,123	Sample with Sx ROA[a] included in analysis n=480
	Mean±SD (range) or %		
Age, years	65.0±9.0 (49.0–83.0)	65.9±8.8 (49.0–83.0)	65.4±8.8 (49.0–83.0)
Sex, women	54.7	54.2	52.03
BMI, kg/m^2	28.4±4.7 (17.2–49.7)	29.0±4.7 (18.2–49.7)	29.6±4.8 (18.2–49.7)
Education, college degree or higher	87.1	85.6	85.6
Race, white	84.0	81.1	78.3
ROA, present	59.9	100.0	100.00
Presence of knee pain in the last 30 days	73.2	78.5	97.5
Knee pain (0–10)	3.0±2.7 (0.0–10.0)	3.4±2.8 (0.0–10.0)	5.0±2.5 (0.0–10.0)
Comorbidity, >1	28.8	30.3	34.3
Lower body pain	58.8	57.0	65.8
Depressive symptoms, CES-D ≥16	11.2	10.3	13.5
Physical activity[b]			
Wear time, minutes	890.3±80.9 (635.0–1,167.8)	887.9±83.1 (657.0–1,167.8)	887.6±85.4 (657.0–1,167.8)
Sedentary time, minutes	590.1±88.8 (222.0–842.1)	590.4±89.2 (237.7–841.7)	590.5±93.4 (237.7–838.1)
Light PA time, minutes	281.7±77.5 (65.0–647.0)	280.3±79.0 (65.0–647.0)	278.7±81.4 (65.0–647.0)
MVPA time, minutes	18.4±19.6 (0.0–162.8)	16.6±18.0 (0.0–136.1)	15.6±16.8 (0.0–136.1)

[a]Symptomatic knee OA was defined as a knee with KL grade >2 and had pain, aching, or stiffness in or around the same knee on most days for >1 month during the past 12 months.

[b]For n=51 participants baseline physical activity monitoring occurred at OAI 72 month visit. Daily minutes averaged over 7 days.

ROA, radiographic knee osteoarthritis; Sx ROA, symptomatic knee osteoarthritis; MVPA, moderate to vigorous intensity physical activity; CES-D, Center for Epidemiologic Studies Depression Scale; VAS, Visual Analogue Scale of the average knee pain in the past 30 days

Table 2

Baseline Physical Function and Physical Activity for Study Subjects Without Functional Limitation at Baseline and With and Without Incident Functional Limitation at Follow-up

Baseline physical function and physical activity	Incident performance-based measure of functional limitation (Slow gait speed, <1.0 m/s) N=1,663		Incident disease specific patient-reported functional limitation (WOMAC, >28/68) N=1,769		Incident general patient-reported functional limitation (SF-12, <40/100) N=1,557	
	Yes n=127	No n=1536	Yes n=195	No n=1574	Yes n=278	No n=1279
Physical function, m/s	1.13±0.10	1.37±0.18	14.0±8.8	4.9±6.8	48.1±5.0	52.7±5.3
Sedentary, minutes	605.3±88.4	586.8±88.6	588.5±92.5	591.4±87.3	587.2±88.7	591.8±87.3
Light intensity, minutes	246.9±69.5	288.5±76.9	279.3±87.7	282.2±75.3	273.4±83.9	286.4±74.3
Moderate-to-vigorous intensity, minutes	6.7±10.4	20.4±20.2	13.3±14.9	19.4±20.1	14.1±17.8	21.3±20.4

Notes: Presented as mean±SD.

WOMAC, Western Ontario and McMasters University Osteoarthritis Index Physical Function Scale; m/s, meters per second; SF-12, 12-item Short From health survey