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Relation of physical activity time to incident disability in community dwelling adults with or at risk of knee arthritis: prospective cohort study

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Abstract

Objective To investigate whether objectively measured time spent in light intensity physical activity is related to incident disability and to disability progression.

Design Prospective multisite cohort study from September 2008 to December 2012.

Setting Baltimore, Maryland; Columbus, Ohio; Pittsburgh, Pennsylvania; and Pawtucket, Rhode Island, USA.

Participants Disability onset cohort of 1680 community dwelling adults aged 49 years or older with knee osteoarthritis or risk factors for knee osteoarthritis; the disability progression cohort included 1814 adults.

Main outcome measures Physical activity was measured by accelerometer monitoring. Disability was ascertained from limitations in instrumental and basic activities of daily living at baseline and two years. The primary outcome was incident disability. The secondary outcome was progression of disability defined by a more severe level (no limitations, limitations to instrumental activities only, 1-2 basic activities, or ≥3 basic activities) at two years compared with baseline.

Results Greater time spent in light intensity activities had a significant inverse association with incident disability. Less incident disability and less disability progression were each significantly related to increasing quartile categories of daily time spent in light intensity physical activities (hazard ratios for disability onset 1.00, 0.62, 0.47, and 0.58, P for trend=0.007; hazard ratios for progression 1.00, 0.59, 0.50, and 0.53, P for trend=0.003) with control for socioeconomic factors (age, sex, race/ethnicity, education, income) and health factors (comorbidities, depressive symptoms, obesity, smoking, lower extremity pain and

function, and knee assessments: osteoarthritis severity, pain, symptoms, prior injury). This finding was independent of time spent in moderate-vigorous activities.

Conclusion These prospective data showed an association between greater daily time spent in light intensity physical activities and reduced risk of onset and progression of disability in adults with osteoarthritis of the knee or risk factors for knee osteoarthritis. An increase in daily physical activity time may reduce the risk of disability, even if the intensity of that additional activity is not increased.

Introduction

Disability is a leading driver of healthcare costs, accounting for more than one in four dollars spent on healthcare.[1] Medical spending among older adults is more strongly related to the presence of disability than to remaining life expectancy.[2] More than 18% of people in the United States were classified as disabled in 2010, at an estimated annual cost of $357bn (£214bn; €259bn).[3]

Participation in physical activity is a low cost, broadly applicable approach to improve health outcomes and reduce the risk of developing chronic disease.[4-10] Randomized controlled trials in adults show that increased physical activity is effective in reducing disability.[11 12] Guidelines recommend 150 minutes each week of moderate to vigorous physical activity,[13] but whether that intensity or time is needed to reduce disability is not known. In the absence of randomized clinical trials to evaluate a dose-response between time spent in specific

intensities of physical activity and disability,[13] to inform public health interventions we examined this question by using longitudinal data from community dwelling adults at elevated risk of disability due to osteoarthritis of the knee or risk factors for knee osteoarthritis (such as obesity).

This study examined whether moderate-vigorous activity is uniquely related to a reduced risk of developing disability or whether light intensity activities may also play a role. It tested the hypothesis that more time spent in light intensity physical activity is separately related to reduced incident disability and progression of disability independent of moderate-vigorous activity and other predictors of risk of disability. We investigated the association between time spent in daily light intensity activity verifiably measured by accelerometer monitoring and subsequent two year incident disability determined from longitudinal systematic reports of limitations in instrumental and basic activities of daily living. We examined this relation among community dwelling adults at elevated risk of disability related to knee osteoarthritis or risk factors for knee osteoarthritis, whose non-sedentary time is largely characterized by light intensity activities.[14]

Methods

Design overview

This was a prospective multisite cohort study of community dwelling older adults at elevated risk of disability related to the presence of osteoarthritis of the knee or risk factors for knee osteoarthritis. Baseline measurement took place from September 2008 to December 2010; follow-up was from September 2010 to December 2012, two years after baseline assessment.

Participants

Participants were a subcohort from the Osteoarthritis Initiative (OAI). The OAI longitudinal study enrolled 4796 men and women aged 45-79 years with or at high risk of developing knee osteoarthritis, a major risk factor for disability. OAI enrollment (2004 to 2006) and biennial follow-up visits took place at four clinical sites (Baltimore, Maryland; Columbus, Ohio; Pittsburgh, Pennsylvania; and Pawtucket, Rhode Island). Adults eligible for the OAI were either required to have osteoarthritis with symptoms in at least one knee (a definite tibiofemoral osteophyte (osteophyte grade ≥ 1[15]) and pain, aching, or stiffness on most days for at least one month during the previous 12 months) or required to have at least one from a set of established risk factors for knee osteoarthritis: knee symptoms in the previous 12 months; overweight, defined using sex and age specific weight thresholds; knee injury causing difficulty walking for at least a week; history of knee surgery; family history of a total knee replacement for osteoarthritis in a biologic parent or sibling; Heberden's nodes; repetitive knee bending at work or outside work; and age 70-79 years. OAI eligibility criteria are detailed elsewhere.[16 17]

We drew the disability onset risk cohort free of baseline disability in instrumental or basic activities of daily living, shown in figure 1⇓, from the 2127 participants enrolled in an OAI accelerometer monitoring substudy at the OAI 48 month clinic visit (2008-10),[14] which was the baseline for the study reported here. To make statements about incident disability, we excluded 174 people reporting baseline disability limitations in instrumental or basic activities of daily living; also excluded were 179 participants with insufficient baseline accelerometer monitoring, 15 participants with incomplete outcome/covariate data, 13 decedents, and 66 participants not available two years later. After these exclusions, 1680 adults without baseline

disability contributed to analyses for two year incident disability. Secondary analyses of two year disability progression evaluated a disability progression risk cohort of 1814 people free of severe baseline disability (1680 without baseline disability plus 134 with baseline mild/moderate disability, as defined below).

Outcomes

We defined disability, using the operational definition of Fried and colleagues, as "difficulty or dependency in carrying out activities essential to independent living, including essential roles, tasks needed for self-care and living independently in a home, and desired activities important to one's quality of life."[18] We identified disability from limitations in performing basic activities of daily living and higher level instrumental tasks on the basis of an affirmative response to a validated questionnaire using the stem "Exclude any difficulties you expect to last less than three months. Because of a health or memory problem do you have any difficulty. . ."[19] Instrumental activities of daily living tasks were preparing hot meals, grocery shopping, making telephone calls, taking drugs, and managing money. Basic activities of daily living tasks were walking across a room, dressing, bathing, eating, using the toilet, and bed transfer. When a specific task response was missing, we imputed the information from the report of extreme difficulty to a parallel item from the late life disability questionnaire for 117 (7%) participants.[20] Sensitivity assessments omitting inferred task limitations yielded almost identical results.

The primary outcome was the development of disability (instrumental or basic activities of daily living) at the two year follow-up visit among adults free of baseline disability. A secondary outcome was disability progression, based on a change from the baseline disability level to a more severe level two years later. Disability levels were none (no activities of daily living limitations), mild (only instrumental activities of daily living limitations), moderate (1-2 basic activities of daily living limitations), and severe (≥ 3 basic activities of daily living limitations).[21 22]

Primary risk factor

Physical activity was monitored using ActiGraph GT1M accelerometers. Trained research personnel gave uniform scripted in-person instructions to wear the accelerometer for seven consecutive days on a belt at the natural waistline on the right hip in line with the right axilla from arising in the morning until retiring, except during water activities. Participants recorded on a daily log the time spent in water and cycling activities, which may not be fully captured by accelerometers.

Accelerometer output is an activity count, which is the weighted sum of the accelerations measured over a minute, where the weights are proportional to the magnitude of acceleration. We defined non-wear periods as at least 90 minutes with zero activity counts (allowing for two consecutive interrupted minutes with counts ≤ 100). We identified participants with the four to seven valid monitoring days (that is, 10 or more wear hours per day) needed for reliable estimates of physical activity.[23] We applied intensity thresholds used by the National Cancer Institute on a minute by minute basis to identify non-sedentary activity of light intensity ($100 \leq counts/minute < 2020$) and moderate to vigorous intensity (counts/minute ≥ 2020) activity.[23]

Our primary risk factor used accelerometer assessment of physical activity measured as daily minutes spent in light or moderate-vigorous intensity activity. For analysis purposes, we determined quartile categories of time spent in light and moderate-vigorous activities by using 1680 participants without

baseline disability. We determined quartile cut points for light activity (229, 277, and 331 average minutes/day) and moderate-vigorous activity (4.3, 12.2, and 28.2 average minutes/day).

Covariates

Socioeconomic factors recorded were race/ethnicity (African-American, white, or other race), age, sex, education, and income. Health factors were comorbid chronic conditions, knee specific health factors, and health behaviors. In addition to osteoarthritis, chronic conditions ascertained by self report of diagnosis by a physician were cancer, cerebrovascular disease, congestive heart failure, diabetes, gastrointestinal disease, pulmonary disease, kidney problems, myocardial infarction, other rheumatic disease, and vascular disease. Body mass index was classified as normal (18.5-24.9), overweight (25.0-29.9), or obese (30 and above) calculated from measured height and weight (weight (kg)/height (m)^2). Severity of depressive symptoms was ascertained by the Center for Epidemiological Studies depression scale (range 0-60).[24] Self reported lower extremity symptoms were pain, aching, or stiffness in the ankle or foot for more than half the previous 30 days or in the hip in the previous 12 months. Knee specific health factors were person level severity of knee osteoarthritis (highest Kellgren-Lawrence grade of both knees assessed from a "fixed flexion" knee radiography protocol at or before the OAI 48 month assessment)[25]; knee symptoms defined as pain, aching, or stiffness on most days of a month during the previous year in either knee; self reported previous knee injury resulting in walking difficulty for at least one week; and person level severity of knee pain (highest (worst) Western Ontario and McMaster University Osteoarthritis pain index score of both knees; range 0-20). If a baseline (OAI 48 month visit) health factor was missing (2.6%, n=47), we used the most recent annual assessment as a proxy. Health behaviors included the report of current smoking and function ascertained by gait speed based on a 20 foot walk test.

Statistical analyses

Univariate analyses of linear trend effects used a Mantel-Haenszel test for ordinal categories, χ^2 test for nominal categories, and linear regression for continuous characteristics. We estimated hazard ratios from survival analysis for discrete data in 1680 adults free of baseline disability to investigate a graded relation between baseline physical activity quartile categories and the development of disability within two years.[26] Secondary analyses evaluated hazard ratios for disability progression among 1814 adults free of severe disability at baseline. Recognizing that systematic differences between people included in and excluded from the analysis sample could influence our findings, we did weighted analyses as recommended by Hogan.[27] For simplicity, we report unweighted analyses, because weighted analyses mirrored those findings. Sensitivity analyses evaluated the stability of results to the cut point separating moderate-vigorous from light intensity activity suggested by Triano and colleagues (that is, 2020 counts/minute[23]) by using alternative cut points in the accelerometer literature (1952[28] and 1269[29]). These analyses regressed the hazard for disability onset on quartile categories of light activity time based on alternative cut points, controlling for socioeconomic and health factors and moderate-vigorous physical activity. Our analyses used public data from the Osteoarthritis Initiative (www.oai.ucsf.edu/datarelease/). Statistical testing used a nominal α=0.05 level, and we used SAS software version 9.3.

Results

We documented 149 cases of new disability in instrumental or basic activities of daily living over two years among the 1680 adults aged 49-83 years and free of baseline disability with or at high risk of osteoarthritis of the knee who completed accelerometer physical activity monitoring, disability assessments, and covariate data. This cohort averaged 302 minutes/day of non-sedentary activity, of which the vast majority was light intensity activities (284 minutes/day). Table 1⇓ shows the baseline characteristics of this cohort stratified by quartile categories of light activity time. Participants who spent the least time in light physical activities were more likely to be older, male, and obese and to have comorbidities, severe knee osteoarthritis, and poorer function and less likely to have lower extremity symptoms.

Primary outcome: incident disability

Light activity time at baseline had a strong inverse relation with the development of disability. In age adjusted analyses shown in figure 2⇓, the frequency of incident disability two years later was greatest among the quartile categories who spent the least time in light physical activity and the least time in moderate-vigorous activity. Stratified age adjusted analyses (not shown) showed significantly lower frequencies of incident disability related to greater light activity time among men (n=765; hazard ratios 1.00, 0.51, 0.48, and 0.56; P for trend=0.042), women (n=915; hazard ratios 1.00, 0.64, 0.42, and 0.56; P for trend=0.037), adults with knee osteoarthritis (n=1006; hazard ratios 1.00, 0.67, 0.43, and 0.64; P for trend=0.037), and adults without knee osteoarthritis (n=674; hazard ratios 1.00, 0.43, 0.47, and 0.46; P for trend=0.042). We found similar significant trends in relation to quartile categories of daily moderate-vigorous activity time stratified by men (n=765; hazard ratios 1.00, 0.58, 0.42, and 0.29; P for trend<0.001), women (n=915; hazard ratios 1.00, 0.38, 0.53, and 0.20; P for trend<0.001), adults with knee osteoarthritis (n=1006; hazard ratio 1.00, 0.65, 0.47, and 0.35; P for trend<0.001), and adults without knee osteoarthritis (n=674; hazard ratios 1.00, 0.25, 0.49, and 0.18; P for trend=0.001).

In multivariate analyses (table 2⇓), greater time spent in light activities was significantly related to lower risk of developing disability in instrumental or basic activities of daily living after simultaneous control for socioeconomic and health factors. For increasing quartile categories of light activity time, the hazard ratios for incident disability decreased: 1.00, 0.62, 0.47, and 0.58, respectively (P for trend=0.007). A significant relation persisted after further control for time spent in moderate-vigorous activities (hazard ratios 1.00, 0.64, 0.51, and 0.67; P for trend=0.039). The only other significant multivariate predictors of incident disability (not shown) were depression and lower extremity pain (see supplementary tables).

We found a strong association between increasing quartile categories of moderate-vigorous activity time and reduced risk of incident disability in multivariate analyses controlled for socioeconomics, health factors, and time in light activities (hazard ratios 1.00, 0.57, 0.63, and 0.38; P for trend=0.005) (table 2⇓). These findings show a decreased risk of subsequent incident disability associated with greater daily time spent in light activities and in moderate-vigorous activities. Furthermore, the inverse relation of light intensity activity time with disability was independent of moderate-vigorous activity time and vice versa.

Secondary outcome: disability progression

Recognizing that many older adults in the community live with disabilities, we broadened our analyses to evaluate progression of disability among 1814 adults free of severe baseline limitations in instrumental or basic activities of daily living. In age adjusted analyses shown in figure 3⇓, the greatest disability progression occurred among quartile categories who spent the least time in light physical activity and the least time in moderate-vigorous activity. This inverse graded relation persisted in multivariate analyses controlled for socioeconomic factors, health factors, and moderate-vigorous activity time (table 3⇓). The hazard ratios for disability progression decreased across increasing quartile categories of light activity time (1.00, 0.61, 0.54, and 0.60; P for trend=0.018). Similarly, we found a significant inverse graded relation between quartile categories representing more time spent in moderate-vigorous activities and disability progression, with control for socioeconomic factors, health factors, and light activity time (hazard ratios 1.00, 0.68, 0.66, and 0.41; P for trend=0.007).

Sensitivity analyses

We did sensitivity analyses (not shown) in which we added 79 decedents/withdrawals by attributing to each the worst disability outcome. Results showed a significant inverse relation of light activity time quartile categories with incident disability and with disability progression, with control for socioeconomic factors, health factors, and moderate-vigorous activity time. Similarly, we found a significant inverse relation of moderate-vigorous activity time quartile categories with incident disability and with disability progression, with control for socioeconomic factors, health factors, and light activity time. Finally, sensitivity analyses based on alternative cut points defining light physical activity showed an inverse association with the development of disability, with control for socioeconomic factors, health factors, and moderate-vigorous activity time (cut point=1952 counts/minute: significant trend; cut point=1269: trend present but attenuated to non-significant).

Discussion

The primary finding from this longitudinal study in community dwelling adults with or at high risk of osteoarthritis of the knee shows a significant inverse relation between daily time spent in light intensity physical activity and risk of developing disability. Importantly, this relation was independent of the time spent in moderate or vigorous activities. This finding is important because adults who are not candidates to increase the intensity of activity owing to health limitations may benefit from increasing the time spent in light intensity activities. As expected, we found an inverse relation between daily time spent in moderate-vigorous activities and the development of disability, consistent with the many health benefits tied to physical activity of moderate or vigorous intensity.[30-35] Together, these findings suggest that increasing daily time spent being physically active may reduce the risk of disability, irrespective of the intensity of that additional activity.

Notably, all quartile categories representing greater daily time in light activities showed a significantly reduced risk of incident disability compared with the group with the least daily light activity time. An average person in the second quartile category of light activity (mean 255 minutes/day) had a 43% reduction in the age adjusted hazard for developing disability compared with the average person in the quartile category spending the least time in light activity (mean 192 minutes/day). Small increases in moderate-vigorous activity were associated with a

reduced risk of disability. An average person in the second quartile category of moderate-vigorous activity time (mean 18 minutes/day) had a 53% reduction in the age adjusted hazard for developing disability compared with the average person in the quartile category spending the least time in moderate-vigorous activity (mean 12 minutes/day). The reduction in risk of incident disability related to small time increments in moderate-vigorous activity bolsters the recognized benefits of those activities. Our findings additionally suggest that increasing time spent in physical activity through light activities may be beneficial towards the goal of maintaining personal independence.

A striking inverse relation between time spent in light activity and incident disability was seen in the group of adults with knee osteoarthritis. This finding is relevant to more than 250 million people worldwide with knee osteoarthritis.[36] Nearly two thirds of obese adults are expected to develop symptoms of knee osteoarthritis at some point in their lives.[37] Osteoarthritis affecting the knee is a primary cause of arthritis related disability and its costs.[38 39] A major cost component related to knee osteoarthritis is total knee replacement surgery. The demand for total knee arthroplasties is expected to more than double in the next decade.[40] As many as half of adults with osteoarthritis of the knee are inactive,[14 41] on the basis of US federal guidelines (that is, absence of any moderate activity lasting at least 10 minutes over an entire week[13]). Such inactive people could substantially reduce their risk of disability and potentially postpone or eliminate the need for arthroplasty in end stage disease by increasing the time spent in physical activity of any intensity.

Findings in relation to other studies

Although the beneficial effects of participation in regular physical activity are widely accepted, the potential benefit of light intensity activity is unclear. Randomized controlled trials focus on benefits of moderate and vigorous physical activity. Exercise programs are effective in reducing mortality and can improve disease related symptoms such as pain, functional limitation, and depression.[4 9 10 42 43] Randomized control trials show a dose-response relation of greater intensity or intensity/frequency of exercise with improved cardiovascular fitness, fewer functional limitations, and less depression.[4 12 44 45] An important randomized control trial by Martin and colleagues showed a dose-response relation between a program delivering four levels of exercise intensity/frequency and reduced disability scores over six months.[46] Published prospective observational studies such as those summarized by Paterson and colleagues show an inverse relation between increasing self reported activity intensity levels (for example, sedentary, light intensity, moderate intensity) or escalating intensity/frequency levels and the development of disability.[47]

In contrast to these studies, we evaluated the relation of time spent in verifiable light intensity activities with subsequent disability. Our study using objective physical activity measures shows a reduced risk of developing disability related to greater time spent in light intensity physical activities. Importantly, this relation held after we controlled for time spent in moderate-vigorous activity and other predictors of risk of disability. To our knowledge, this study is the first to show an inverse relation between light activity time and the development of disability.

Moderate-vigorous activity is well established as being related to good health outcomes, including reduced disability. Our results indicate that increasing light activity is also beneficial,

independent of moderate-vigorous activity. Our findings support the testing of interventions to increase both light and moderate-vigorous activity. Our results have implications for adults who may not be candidates for participating in moderate activity, such as people who are limited by cardiac or pulmonary restrictions or have mobility barriers due to pain. These results indicate that increasing light activity independent of moderate-vigorous activity may be related to less subsequent disability.

Strengths and weaknesses of study

Strengths of this study included prospective data collection across multiple sites, the large sample size, and the age and sex diversity of this sample. Results from this observational study may be influenced by reverse causation or confounded by factors associated with unmeasured disability at baseline, influencing both low levels of physical activity and increased risk of disability. We mitigated this concern by restricting our analyses to people free of disability at baseline, assessing subsequent disability status two years later, and controlling for baseline gait speed, which is arguably a precursor of disability. In addition, our analyses controlled for major confounders including baseline chronic conditions, socioeconomic factors, obesity status, depressive symptoms, and pain to minimize this concern. Although multivariate control for potential confounders attenuated the beneficial relation of light activity time to incident disability, the only significant factors were depressive symptoms and lower extremity pain, showing the strength of physical activity relative to these other recognized but non-significant risk factors.

The sample was composed of adults with or at high risk of developing knee osteoarthritis, which influences the generalizability of these results. However, the relation between time spent in light activity and incident disability held within subgroups with and without knee osteoarthritis, supporting the robustness of this relation to disease status. Although an important methodological strength is the objective measurement of physical activity with accelerometers, the cut point used to define light intensity activity may influence the strength of association with disability. Finally, causation cannot be inferred from these observational data.

Conclusions

These prospective data from a large study of diverse community dwelling adults with or at high risk of knee osteoarthritis showed a significant and consistent relation between greater time spent in light intensity activity and a reduced risk of development or progression of disability. Our findings confirm that more moderate-vigorous activity time was related to less subsequent onset and progression of disability. Importantly, greater light activity time, independent of time spent in moderate-vigorous intensity activity, was significantly related to reduced risk and progression of disability. Our findings provide encouragement for adults who may not be candidates to increase the intensity of physical activity owing to health limitations. Greater daily physical activity time may reduce the risk of disability, even if the intensity of that additional activity is not increased.

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What is already known on this topic

Disability is a leading driver of healthcare costs, accounting for more than one in four dollars spent on healthcare

Participation in physical activity is a low cost, broadly applicable approach to improve health outcomes including reduction of disability

Physical activity guidelines recommend engaging in moderate-vigorous intensity physical activity, but whether that intensity is needed to reduce disability is not known

What this study adds

Greater daily time spent in light intensity physical activities objectively measured by accelerometer was significantly related to a reduced risk of developing disability and disability progression

Importantly, this relation held after control for daily time spent in moderate-vigorous intensity activities and other predictors of disability risk

These findings suggest that more time spent being physically active reduces the risk of disability even if the intensity of activity is not increased

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Tables

Table 1| Baseline characteristics of 1680 adults at risk of disability onset. Values are percentages (numbers) unless stated otherwise

Characteristics	Quartile category of light physical activity daily time				P value (trend)*
	1 (lowest) (n=423)	2 (n=415)	3 (n=423)	4 (highest) (n=419)	
Socioeconomic factors					
Mean (SD) age in years	67.8 (9.7)	65.3 (8.9)	63.9 (8.5)	62.4 (7.9)	<0.001
White race/ethnicity	85.8 (363)	87.0 (361)	84.9 (359)	81.4 (341)	0.370
Female sex	43.3 (183)	51.1 (212)	59.6 (252)	64.0 (268)	<0.001
Education: high school or less	11.1 (47)	12.8 (53)	11.4 (48)	13.4 (56)	0.453
Income <$50 000†	33.1 (140)	28.2 (117)	28.6 (121)	32.9 (138)	0.986
Health factors					
Body mass index:					
Normal: 20-25	22.7 (96)	26.5 (110)	26.7 (113)	28.4 (119)	0.006
Overweight: 25-29.9	35.9 (152)	41.0 (170)	40.9 (173)	39.9 (167)	
Obese: ≥30	41.4 (175)	32.5 (135)	32.4 (137)	31.7 (133)	
Comorbidity‡:					
Cancer	8.0 (34)	5.5 (23)	2.8 (12)	4.1 (17)	0.002
Cerebrovascular disease	5.4 (23)	3.9 (16)	1.7 (7)	2.4 (10)	0.004
Congestive heart failure	4.5 (19)	1.7 (7)	1.9 (8)	1.4 (6)	0.007
Diabetes	13.5 (57)	6.5 (27)	10.6 (45)	8.4 (35)	0.081
Gastrointestinal disease	2.6 (11)	2.7 (11)	2.1 (9)	1.4 (6)	0.209
Pulmonary disease	11.8 (50)	8.9 (37)	6.9 (29)	12.2 (51)	0.867
Kidney problems	2.6 (11)	2.2 (9)	1.7 (7)	1.0 (4)	0.063
Myocardial infarction	2.8 (12)	1.7 (7)	2.6 (11)	1.9 (8)	0.562
Rheumatic disease other than osteoarthritis	3.8 (16)	1.0 (4)	1.7 (7)	1.9 (8)	0.111
Vascular disease	1.9 (8)	1.5 (6)	0.5 (2)	1.2 (5)	0.204
Mean (SD) depressive symptom score§	6.8 (7.5)	6.0 (6.8)	5.8 (7.0)	6.6 (7.1)	0.598
Lower extremity pain, aching, or stiffness ¶	51.8 (219)	59.0 (245)	58.9 (249)	63.5 (266)	0.001
Knee osteoarthritis severity**:					
Grade 0 or 1	37.1 (157)	40.7 (169)	40.4 (171)	42.2 (177)	0.045
Grade 2	30.5 (129)	31.1 (129)	31.0 (131)	30.6 (128)	
Grade 3	21.3 (90)	20.0 (83)	19.6 (83)	20.5 (86)	
Grade 4	11.1 (47)	8.2 (34)	9.0 (38)	6.7 (28)	
Knee symptoms††	37.4 (158)	37.6 (156)	39.7 (168)	36.3 (152)	0.920
Previous knee injury	51.5 (218)	49.2 (204)	48.7 (206)	51.3 (215)	0.913
Mean (SD) knee pain‡‡	2.7 (3.2)	2.3 (2.9)	2.3 (2.9)	2.6 (3.2)	0.676
Current smoker	4.0 (17)	3.4 (14)	2.4 (10)	4.3 (18)	0.959
Function: mean (SD) gait speed in feet/second	4.3 (0.7)	4.4 (0.6)	4.5 (0.6)	4.5 (0.6)	<0.001
Physical activity					
Mean (SD) light activity in minutes/day	192.3 (29.2)	254.9 (14.2)	302.1 (15.7)	385.9 (50.0)	<0.001
Mean (SD) moderate-vigorous activity in minutes/day	13.1 (17.6)	18.0 (19.2)	20.3 (18.6)	24.3 (20.9)	<0.001

*Test for trend used Mantel-Haenszel χ^2 test (df=1) except for χ^2 test for overall differences for race and sex comparisons, and linear regression for continuous factors age, depressive symptom score, knee pain, gait speed, light activity minutes/day, and moderate activity minutes/day.

†Income less than $50 000 (£30 000; €36 000) per year or not reported.

Table 1 (continued)

Characteristics	Quartile category of light physical activity daily time				P value (trend)*
	1 (lowest) (n=423)	2 (n=415)	3 (n=423)	4 (highest) (n=419)	

‡Participants could contribute to more than one of listed comorbidities.

§Center for Epidemiological Studies depression score.

¶Hip, ankle, or foot.

**Highest Kellgren-Lawrence grade of both knees.

††Knee symptoms based on report of pain, aching, or stiffness most days in month for previous 12 months.

‡‡Western Ontario and McMaster University osteoarthritis index pain score.

Table 2| Hazard ratios for onset of disability* (n=1680) among quartile categories light activity time and moderate-vigorous activity time

	Quartile categories—hazard ratio (95% CI) relative to category 1				
	1 (least time)	2	3	4 (most time)	P value (trend)†
Categories defined from daily light intensity activity time‡					
Unadjusted	1.00	0.56 (0.37 to 0.86)	0.43 (0.27 to 0.68)	0.54 (0.35 to 0.83)	0.001
Socioeconomic§ and health¶ factors	1.00	0.62 (0.40 to 0.96)	0.47 (0.29 to 0.76)	0.58 (0.36 to 0.92)	0.007
Socioeconomic§ and health¶ factors plus moderate-vigorous activity	1.00	0.64 (0.41 to 0.99)	0.51 (0.31 to 0.83)	0.67 (0.41 to 1.07)	0.039
Categories defined from daily moderate-vigorous activity time**					
Unadjusted	1.00	0.49 (0.32 to 0.74)	0.51 (0.34 to 0.78)	0.28 (0.17 to 0.47)	<0.001
Socioeconomic§ and health¶ factors	1.00	0.54 (0.34 to 0.85)	0.57 (0.35 to 0.92)	0.34 (0.18 to 0.62)	<0.001
Socioeconomic§ and health¶ factors plus light activity	1.00	0.57 (0.36 to 0.91)	0.63 (0.38 to 1.04)	0.38 (0.20 to 0.72)	0.005

*Ascertained from instrumental or basic activities of daily living task limitations.

†Linear trend test.

‡Light activity quartile categories in minutes per day: Q1, <229 (n=423); Q2, 229-275 (n=415); Q3, 275-328 (n=423); Q4, ≥328 (n=419).

§Age, sex, race/ethnicity, education, and income.

¶Comorbidities (cancer, cerebrovascular disease, congestive heart failure, diabetes, gastrointestinal disease, pulmonary disease, kidney problems, myocardial infarction, rheumatic disease other than osteoarthritis, vascular disease), Center for Epidemiological Studies depression score, body mass index category, current smoking, knee osteoarthritis severity (Kellgren-Lawrence grade), knee pain (Western Ontario and McMaster University osteoarthritis score), knee symptoms, knee injury, other lower extremity joint pain, gait speed.

**Moderate-vigorous activity quartile categories in minutes per day: Q1, <4.3 (n=423); Q2, 4.3-12.1 (n=417); Q3, 12.2-28.1 (n=421); Q4, ≥28.2 (n=419).

Table 3| Hazard ratio for disability progression* (n=1814) among quartile categories of light activity time and moderate-vigorous activity time

	Quartile categories—hazard ratio (95% CI) relative to category 1				P value (trend ††)
	1 (least time)	**2**	**3**	**4 (most time)**	
Categories defined from daily light intensity activity time‡					
Unadjusted	1.00	0.55 (0.37 to 0.83)	0.45 (0.29 to 0.69)	0.50 (0.33 to 0.77)	<0.001
Socioeconomic§ and health¶ factors	1.00	0.59 (0.38 to 0.90)	0.50 (0.32 to 0.79)	0.53 (0.34 to 0.83)	0.003
Socioeconomic§ and health¶ factors plus moderate-vigorous activity	1.00	0.61 (0.39 to 0.93)	0.54 (0.34 to 0.86)	0.60 (0.38 to 0.96)	0.018
Categories defined from daily moderate-vigorous activity time**					
Unadjusted	1.00	0.54 (0.36 to 0.80)	0.50 (0.33 to 0.74)	0.28 (0.17 to 0.47)	<0.001
Socioeconomic§ and health¶ factors	1.00	0.63 (0.41 to 0.97)	0.58 (0.36 to 0.94)	0.36 (0.20 to 0.65)	<0.001
Socioeconomic§ and health¶ factors plus light activity	1.00	0.68 (0.44 to 1.05)	0.66 (0.40 to 1.08)	0.41 (0.22 to 0.76)	0.007

*Based on change from baseline disability level to subsequent more severe level at two years in instrumental or basic activities of daily living (IADL/ADL) task limitation levels defined by none (no IADL/ADL limitations), mild (only IADL limitations), moderate (1-2 ADL limitations), severe (≥3 ADL limitations).

†Linear trend test.

‡Light activity quartile categories in minutes per day: Q1, <229 (n=466); Q2, 229-275 (n=447); Q3, 275-328 (n=453); Q4, ≥328 (n=448).

§Age, sex, race/ethnicity, education, and income.

¶Comorbidities (cancer, cerebrovascular disease, congestive heart failure, diabetes, gastrointestinal disease, pulmonary disease, kidney problems, myocardial infarction, rheumatic disease other than osteoarthritis, vascular disease), Center for Epidemiological Studies depression score, body mass index category, current smoking, knee osteoarthritis severity (Kellgren-Lawrence grade), knee pain (Western Ontario and McMaster University osteoarthritis score), knee symptoms, knee injury, other lower extremity joint pain, gait speed.

**Moderate-vigorous activity quartile categories in minutes per day: Q1, <4.3 (n=478); Q2, 4.3-12.1 (n=455); Q3, 12.2-28.1 (n=450); Q4, ≥28.2 (n=431).
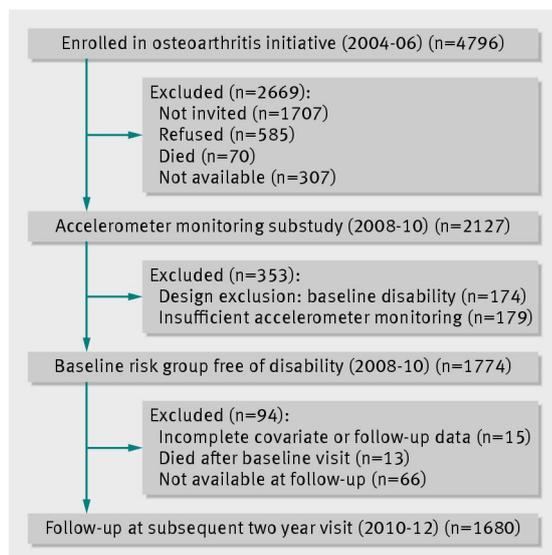
Figures

Fig 1 Flow of analytical sample of accelerometer participants at risk of disability onset through study follow-up
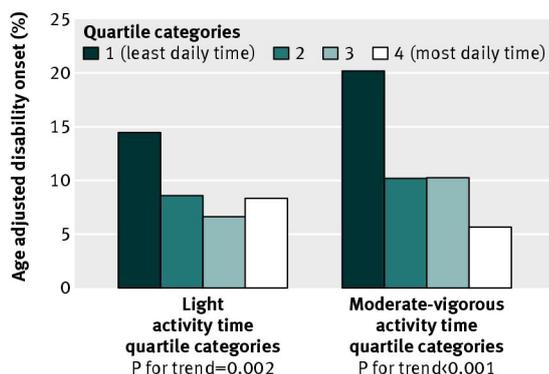

Fig 2 Age adjusted percentage of incident disability according to quartile categories of light physical activity and moderate-vigorous physical activity (n=1680)
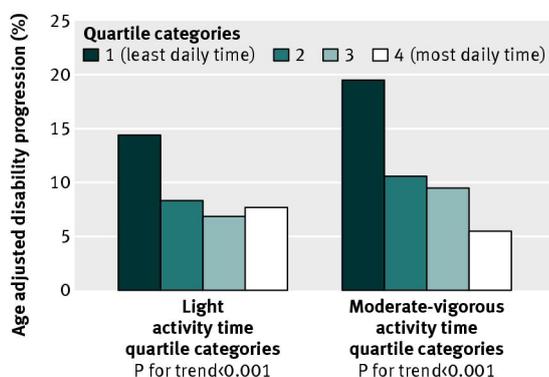

Fig 3 Age adjusted percentage of disability progression according to quartile categories of light physical activity and moderate-vigorous physical activity (n=1814)