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Do Inactive Older Adults who Increase Physical Activity Experience Less Disability: Evidence from the Osteoarthritis Initiative

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Abstract

Background—Physical inactivity is a leading risk factor for developing disability. Although randomized clinical trials have demonstrated improving physical activity can reduce this risk in older adults with arthritis, these studies did not specifically evaluate inactive adults.

Objectives—To evaluate the relationship of changes in physical activity with disability changes among initially inactive adults with or at high risk of knee OA from Osteoarthritis Initiative.

Methods—Inactive persons were identified at baseline based on the U.S. Department of Health and Human Services classification (no [zero] 10-minute session of moderate-to-vigorous activity over one week) from objective accelerometer monitoring. Two years later physical activity change status was classified as: (1) met Federal physical activity guidelines (≥150 moderate-to-vigorous minutes/week acquired in bouts ≥10 minutes), (2) insufficiently increased activity (some but <150 moderate-to-vigorous bout minutes/week) or (3) remained inactive. Disability at baseline and two years was assessed by Late Life Disability Instrument (LLDI) limitation and frequency scores. Multiple regression evaluated the relationship of physical activity change status with baseline-to-2 year changes in disability scores adjusting for socioeconomic, health factors, and baseline disability score.

Results—Increased physical activity showed a graded relationship with improved disability scores in LLDI limitation ($P<0.001$) and frequency scores ($P=0.027$). While increasing moderate-

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to-vigorous activity to guideline levels showed the greatest reduction, even insufficiently increased physical activity was related to reduced disability.

Conclusions—Findings support advice to increase moderate-to-vigorous physical activity to reduce disability among inactive adults with or at high risk for knee osteoarthritis, even when guidelines are not met.

INTRODUCTION

Physical inactivity is a costly public health problem. As much as 8.8% of U.S. health costs are associated with physical inactivity.(1) Physical inactivity is associated with increased cardiovascular disease, type 2 diabetes, and premature death.(2) Importantly, physical inactivity is a leading risk factor for disability.(3, 4) Disability increases the risk of hospitalization, institutionalization, loss of independence, and is a major driver of health care costs.(5, 6) This issue is particularly important for adults with arthritis, a group which is likely to be physically inactive and at elevated risk for disability due to joint limitations. Physical inactivity accounted for an estimated 21% of disability attributed to arthritis.(7)

Randomized clinical trials demonstrated structured physical activity can reduce the risk for developing disability in high risk populations (8, 9), including adults with osteoarthritis. (10) But these studies did not specifically evaluate inactive adults. Among adults with arthritis, inactivity approaches endemic proportions. A US national survey found more than 2 in 5 (44%) adults with arthritis to be inactive.(11)

The objective of this study is to investigate among initially inactive adults the relationship of increased physical activity levels with changes in disability over a 2 year period. We adhere to the U.S. Department of Health and Human Services (DHHS) definition of inactivity: the absence of a single 10 minute session of moderate-to-vigorous (MV) activity over an entire week. We evaluated the hypothesis that among initially inactive adults there is a graded relationship between increased physical activity levels and reduced disability severity. This hypothesis is tested among adults with or at high risk of knee osteoarthritis (OA), due to their elevated risk for progressive disability.(12)

MATERIALS AND METHODS

Study sample

This observational study used data from the accelerometer substudy of the Osteoarthritis Initiative (OAI) conducted at baseline (OAI 48-month visit, 2008–2010) and two-year follow-up (OAI 72-month visit, 2010–2012). The OAI is a multi-center study investigating risk factors and biomarkers for the progression and/or onset of knee OA (see <http://www.oai.ucsf.edu/datarelease/About.asp>). At enrollment, the OAI recruited 4796 adults with symptomatic, radiographic knee OA or had at least one from an established list of knee OA risk factors (overweight, prior knee injury, prior knee surgery etc.). OAI eligibility criteria have been described in detail elsewhere.(13) Each participant provided written informed consent. Approval was obtained from the institutional review board at each OAI site and Northwestern University.

The OAI accelerometer ancillary study monitored physical activity on a subcohort of 2127 OAI participants aged 49–83.(14) The present study focused on 545 physically inactive persons at baseline. Excluded by design were 1052 not meeting baseline physical inactivity criteria and 200 having less than four days valid accelerometer monitoring. Another 330 inactive adults were excluded for analysis purposes (47 decedents/withdrawals two years later, 208 did not participate in follow-up accelerometer monitoring, 75 had incomplete data).

Outcome: disability

Disability was measured using the Late Life Disability Instrument (LLDI) (15). The primary outcome is the two-year change in LLDI limitation score from baseline. The limitation score assesses an individual's performance capability across 16 major personal and social life tasks. The limitation score is based on separate responses to the question "To what extent do you feel limited in (doing a particular task)?" Response options were "not at all", "a little", "somewhat", "a lot", and "completely". A secondary outcome is the two-year change from baseline in LLDI frequency score. The frequency score is based on responses to the question "How often do you (do a particular task)?" We also examined changes in different limitation and frequency role domain subscores for insight into the nature of disability changes. LLDI limitation has instrumental (12 tasks) and management (4 tasks) role domains, which identify limitations in activities requiring mobility functioning and limitations in social tasks that involve minimal mobility or physical activity, respectively. LLDI frequency has social (9 tasks) and personal (7 tasks) role domains, which reflect the frequency of performing social/community tasks and personal tasks respectively. The total scores and role domain subscores were scaled to a 0–100 metric scale; higher scores indicate more desirable capability/frequency in performing activities. We calculated change in LLDI scores as the difference between 2-year follow-up and baseline measures. Positive values in change indicate improvement and negative values indicate worsening.

The Late Life Disability Instrument was validated among ethnically and racially diverse adult populations having a range of functional limitations and chronic conditions.(15, 16) and has demonstrated test-retest reliability). (15) The LLDI limitation score two-year change from baseline is designated the primary outcome due to its superior test-retest reliability and sensitivity to change over time.(16)

Physical activity transitions

Longitudinal objective physical activity data were acquired at baseline and two years later. Physical activity monitoring used a GT1M ActiGraph accelerometer (ActiGraph; Pensacola, FL), a small uniaxial accelerometer that measures vertical acceleration and deceleration. Trained research personnel instructed participants to wear the accelerometer on a belt at the natural waistline on the right hip in line with the right axilla upon arising in the morning and continuously until retiring at night, except during water activities, for seven consecutive days. Accelerometer data were analytically filtered using methodology validated in patients with rheumatic disease.(17, 18) Nonwear periods were defined as intervals of at least 90 minutes with zero activity counts allowing for 2 consecutive interrupted minutes with counts below 100. To provide reliable physical activity estimates, we restricted analyses to

participants with 4–7 days of valid accelerometer monitoring (i.e., at least 10 hours of daily wear or monitoring time) at both baseline as well as 2 years.(19)

We calculated the total daily MV minutes (accelerometer count $\geq$ 2020 per minute) occurring in bouts lasting 10 or more minutes, allowing for interruptions of 1 or 2 minutes below the MV threshold.(19) Weekly totals were summed for persons with 7 valid monitoring days or estimated as 7 times the average daily total for persons with 4 to 6 valid monitoring days. The baseline inactive group was identified by the absence of any (zero) bouts of MV activity minutes over one week. From accelerometer monitoring at 2 years, these inactive persons were classified into one of three DHHS physical activity guideline groups (12): (1) met DHHS guidelines (at least 150 minutes/week MV activity acquired in sessions 10min), (2) insufficiently increased MV activity (1 session/week but below guidelines), or (3) remained inactive.

Covariates

Socioeconomic factors measured at baseline included race/ethnicity, age, sex, education, living arrangement, and income. Race/ethnicity (African American, White, or other race) was ascertained from self-report. Education was dichotomized as post high school versus less education or not reported. Living arrangement was based on self-report of living alone or not. Annual income was classified as $\geq$ \$50k, <\$50k or not reported.

Baseline health factors assessed included knee specific health factors (radiographic knee OA, chronic knee symptoms, knee pain, knee injury), general health factors (body mass index, comorbidity, depression, other lower extremity pain), and smoking. Radiographic knee OA was defined by a Kellgren and Lawrence grade $\geq$ 2 in at least one knee at the OAI 48-month visit or earlier. The presence of chronic knee symptoms was ascertained from a positive response to “Do you have pain, aching, or stiffness on most days of a month during the past year” in either knee. Knee pain was evaluated using the maximum value of Western Ontario and McMaster University OA Index scores of the two knees; range = 0 (no pain) – 20, with higher numbers representing worse symptoms. Body mass index [weight (kg)/height (m)²] was calculated from measured height and weight (standard balance beam scale) and classified as normal weight (18.5–24.9), overweight (25.0–29.9), or obese ($\geq$ 30). Presence of comorbidity was ascertained by modified Charlson Comorbidity Index $\geq$ 0.(20) High depressive symptoms were identified by Center for Epidemiological Studies Depression (CESD) scale $\geq$ 16.(21) The presence of other lower extremity pain included self-reported pain in the hip, ankle, and/or foot. If a health factor was missing at the 48 month visit (1.5%, n=8), data from the most recent OAI annual visit was used.

Statistical analysis

Descriptive analyses of baseline characteristics were presented by physical activity transition groups. Univariate analyses of baseline trend effects were evaluated by a Mantel Haenszel test for ordinal categories, Chi-square test for nominal variables, and analysis of variance for continuous variables. The association between changes in disability and the transition in physical activity levels was examined by multiple linear regression adjusted for socioeconomic and health factors. In addition, analyses were adjusted for baseline disability

to control for potential ceiling or floor effects. Differences and corresponding 95% confidence interval (CI) were calculated to compare 2-year change in LLDI limitation and frequency scores among adults who remained inactive with those who improved activity (insufficiently improved and met guidelines at two years). We estimated effect size using Cohen's *d* statistic.(22)

Recognizing systematic differences (e.g. race/ethnicity, education, comorbidity, and WOMAC pain) between inactive participants at baseline included (n=545) and excluded (n=330) could influence findings, we performed weighted analyses recommended by Hogan et al (23) and Robins et al (24). Unweighted analyses are reported for simplicity because results were almost identical with weighted analyses. Because two of the 16 Late Life tasks, were related to physical activity, active recreation and regular fitness program, we performed sensitivity analyses using recalculated LLDI limitation and frequency scores excluding these two specific tasks. Further sensitivity analysis investigated potential influences related to concurrent changes in pain, weight, comorbidity, depression, and seasonal differences. Analyses were performed using SAS software version 9.4 (Cary, NC). Statistical testing was conducted at a two-sided 5% significance level.

RESULTS

The 545 inactive people at baseline evaluated in this study had mean age 67.9 years (range 49 to 83), were 64% female, and 84% white. Most had either radiographic knee OA (64%) and/or chronic knee symptoms (40%). Over two years, one in four inactive adults (28%, 142 participants) increased moderate physical activity but the vast majority remained inactive. Of those who improved their physical activity status, more than 10% met the DHHS physical activity guidelines. The insufficiently active and met guideline groups increased daily moderate activity on average by 7.8 and 31.7 minutes, respectively. Vigorous activity in all three groups was negligible.

Table 1 shows adults who remained inactive compared to those who became more active were significantly more likely to be older, less educated, live alone, low income, had radiographic knee OA, and high depressive symptoms but were less likely to report prior knee injury. There were no notable differences in baseline average total disability scores.

Table 2 displays for the three physical activity groups the primary outcome, the mean two-year changes from baseline in LLDI limitation total scores. On average, those who remained inactive worsened in disability scores (negative change) but the groups which increased activity showed improvement (positive change). Compared to the inactive group, the difference in the two-year change of total limitation score was significantly greater for both the insufficiently active (average difference of 2.6, 95% CI: 0.3, 4.8; effect size=0.22) and met guideline (average difference of 10.2, 95% CI: 4.5, 15.8; effect size=0.87) groups controlling for baseline total limitation score, socioeconomic and health factors. These total limitation score two-year changes across the three groups represent a significantly increasing graded relationship (*P* value for trend <0.001).

Further Table 2 analyses separately examined two-year changes in the LLDI limitation instrumental and management role domain subscores. A significantly greater improvement in both domains was found among adults who became insufficiently active or met guidelines compared to those who remained inactive controlling for covariates. These differences represented a significantly increasing graded relationship for the instrumental (P value for trend <0.001) and management (P value for trend $=0.034$) role domain scores.

Table 3 shows mean two-year changes from baseline in secondary LLDI frequency total score outcome of the three groups. Only those who increased activity to guideline level showed improvement (positive change); the other two groups worsened in total frequency scores (negative change). When compared to those who remained inactive, those who increased activity to meet guidelines significantly improved frequency total score (mean difference $=3.1$, 95% CI: 1.1, 5.2; effect size $=0.75$) controlling for baseline total frequency score, socioeconomic, and health factors. Inactive adults who increased physical activity to become insufficiently active had better but not statistically significant total frequency scores than those who remained inactive (mean difference $=0.3$, 95% CI: -0.5 , 1.1; effect size $=0.07$). These total frequency score differences across physical activity transition groups represent a significantly increasing graded relationship (P value for trend $=0.027$).

Further Table 3 analyses examined two-year changes in LLDI frequency social and personal role domain subscores. A significant increasing graded relationship was found between increasing physical activity levels and improved changes in personal role domain score (P value for trend $=0.002$), but not social role domain score (P value for trend $=0.170$).

Sensitivity analyses used re-calculated disability scores to exclude two tasks related to physical activity. The relationship between physical activity transition and change in disability outcomes persisted. Recognizing concurrent changes in knee pain, body weight, comorbidity, and depressive symptoms (CESD) could potentially influence the observed relationship, we performed sensitivity analyses by including these changes as predictors. Only change in pain and change in depressive symptoms were significantly related to changes in disability scores; however controlling for these additional factors did not change the findings. Additional analyses controlling for potential seasonal influence on physical activity had similar results.

DISCUSSION

In this study of inactive adults, we evaluated the relationship of changes in physical activity levels with changes in disability severity over a two year period. For this purpose we examined adults with knee OA or having knee OA risk factors due to their elevated risk for progressive disability. Initially inactive adults who subsequently met federal physical activity guidelines two years later significantly improved in LLDI disability limitation score, the primary outcome, compared to those who remained inactive. Adults who increased their physical activity from being inactive to insufficiently active also showed significantly improved disability limitation scores compared to those who remained inactive. A significant graded relationship was found between increased physical activity levels and improvement from baseline in disability limitations. These relationships held after adjusting

for differences in baseline socioeconomics, health factors, and baseline disability. Similar although weaker relationships were found for the secondary outcome, LLDI disability frequency scores.

Increasing physical activity is considered a relatively inexpensive strategy to improve health. Previous longitudinal studies investigating the effect of changes in physical activity over a lifetime found increased physical activity is associated with reduced risk of disability.(25, 26) The recent LIFE randomized clinical trial demonstrated a structured physical activity intervention reduced mobility disability in older adults who were initially deemed at high risk for mobility disability. Over an average follow-up period of 2.6 years, 30.1% of participants in the intervention group vs 35.5% of controls experienced major mobility disability.(8) While this strong evidence supports the benefits of physical activity, these investigations do not directly address the question of whether this benefit holds for inactive adults who comprise as much as 55% of the older U.S. population over age 65.(27)

Randomized clinical trials (RCT) targeting adults with osteoarthritis have investigated the effect of structured physical activity on health outcomes. These studies showed that structure physical exercise improved strength and function and reduced pain and depressive symptoms.(28–30) One RCT of community-living older adults with osteoarthritis also found that those who participated in either aerobic walking or strengthening training exercise programs reported less disability in activities of daily living (ADL) than the controlled group.(28) Another study using data from the same clinical trial also showed lower incident ADL disability in the exercise group.(10) However literature provides sparse information on the potential benefits of physical activity among inactive adults with arthritis. To our knowledge, none have evaluated the relationship of the change of general (in contrast to prescribed structured) physical activity to changes in disability.

Physical inactivity has achieved pandemic status with far reaching health consequences.(31) Worldwide as much as 9% of mortality is attributed to physical inactivity. In the U.S. alone, it is estimated inactive people would gain 1.3–3.7 additional years of life by increasing physical activity.(32) To our knowledge, this is the first study examining among inactive adults the relationship between changes in overall physical activity and change in disability.

This study of inactive adults with knee OA or knee OA risk factors demonstrated improvement over time in disability limitations among those who increased moderate intensity physical activity, which is the basis for assessing federal guidelines status. Initially inactive individuals who subsequently met guidelines increased moderate activity two years later by an average 31.7 minutes a day; those who transitioned to insufficient activity increased on average 7.8 minutes per day. The effect size of reduced disability limitations was largest (0.87) for the group which met guidelines and modest (0.22) for the insufficiently active group compared to those remained inactive. These results are encouraging because they support an association between increased physical activities including non-structured physical activity in a community living environment with improvement in disability status. Adding just ten minutes a day of a moderate activity such as walking is a goal that most older adults with arthritis could realistically achieve.

Many mechanisms may contribute to the observed positive relationship of increased physical activity with improved disability scores. Physiologically, it is well known that physical activity is beneficial for muscle strength, aerobic capacity, flexibility, and balance.(2, 33) These physiological benefits could be related to better life task capabilities. It is also possible increased physical activity reflects less pain resulting in improvements in disability status. Another mechanism by which increasing physical activity contributes to improved disability levels may be through improved affect.(34, 35) Although changes in knee pain and changes in depressive symptoms were significantly related to changes in disability, sensitivity analyses indicated greater physical activity retained an independent relationship to improved disability levels even controlling for such factors.

Strengths of our study include the longitudinal cohort study, objective accelerometer physical activity monitoring, and the inclusion of adults with knee OA. Because knee OA is highly prevalent with a lifetime risk of 45%(36), findings from this sample would translate to a large segment of adults. The measurement of disability using the Late-Life Disability Instrument evaluated a broad range of tasks pertaining to personal care as well as community involvement.(15) Some study limitations should be noted. The study is observational and causation cannot be inferred from these observational data; we do not know to what extent change in physical activity influenced change in disability or vice versa. The number of individuals who increased physical activity to levels meeting guidelines was a small percentage of the overall group, which could compromise power. However even in this small group a large effect size was demonstrated. Finally, those who increased activity had different baseline characteristics from those who remained inactive. However, our results held controlling for recognized confounders. Despite these limitations, the strong consistent trends in these data support rationale to encourage physical activity in older inactive adults, even those with knee OA.

CONCLUSIONS

In conclusion, while our findings showed the greatest reduction in disability among adults who increased moderate-to-vigorous physical activity to guideline levels, even insufficiently increased physical activity was related to reduced disability among previously inactive adults with knee OA or knee OA risk factors. These findings support advice to increase moderate-to-vigorous physical activity to reduce disability among inactive adults including persons with knee OA, even when guideline levels are not achieved.

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Table 1

Baseline (2008–2010) Characteristics of n=545 Inactive OAI Participants

Baseline Characteristics	Remained Inactive (n=393)	Insufficiently Active (n=137)	Met Guidelines (n=15)	<i>P</i> value ^g
	% or mean (SD)	% or mean (SD)	% or mean (SD)	
Socioeconomics				
Age in years: 65 or older	71.3	43.8	40.0	<0.001
Race/ethnicity:				0.280
White	81.9	88.3	93.3	
African American	15.5	8.8	6.7	
Other	2.5	2.9	0.0	
More than high school education	80.9	89.8	93.3	0.010
Female	66.2	56.2	66.7	0.110
Live alone	27.2	21.2	6.7	0.036
Yearly income <\$50k	46.8	23.4	46.7	<0.001
Health Factors				
Presence or radiographic knee OA or knee symptoms	77.4	70.1	53.3	0.013
Radiographic knee OA ^a	66.9	59.1	33.3	0.006
Presence of knee symptoms ^c	42.0	36.5	26.7	0.124
WOMAC pain score ^b , mean (SD)	3.1 (3.7)	2.4 (2.9)	2.0 (2.5)	0.074
Prior knee injury	42.5	56.2	46.7	0.019
Lower extremity pain	60.3	62.8	80.0	0.212
Body mass index category				0.086
<25	17.6	27.0	20.0	
25–29.9	37.4	31.4	46.7	
30	45.0	41.6	33.3	
Presence of comorbidity ^d	35.4	31.4	33.3	0.454
High depressive symptoms ^e	15.3	8.0	0.0	0.008
Current smoker	5.9	4.4	0.0	0.287
LLDI Disability scores ^f				
Limitation Total Score	79.3 (15.3)	82.1 (14.5)	78.3 (12.8)	0.161
Frequency Total Score	55.0 (5.9)	55.2 (5.9)	55.0 (6.0)	0.915

Abbreviations: LLDI, Late Life Disability Instrument; OA, osteoarthritis; SD, standard deviation; WOMAC, Western Ontario and McMaster University OA Index.

^aKellgren and Lawrence grade 2

^bKnee symptoms based on report of pain, aching, or stiffness most days in month past 12 mo

^cWOMAC pain score in the more symptomatic (painful) knee

^dModified Charlson Index Score

^eCenter for Epidemiological Studies Depression scale 16

^fLLDI disability scores were scaled to a 0–100 metric scale with higher scores indicate more desirable capability/frequency and lower scores indicate less capability/frequency in performing activities.

^gDetermined by Chi-square test for categorical variables (for race and BMI, tests were done using the multi-level categorical variables), and analysis of variance for WOMAC pain score and baseline LLDI disability scores.

Table 2

Disability in LLDI Limitation Dimension: Mean Two-year Change^a, Difference in Change Related to a Transition to More Active Status Versus Remaining Inactive (n=545), 2008–2012.

	LLDI Limitation Dimension	Year 2 Activity Status Among Baseline Inactive Adults			
		Remained Inactive	More Active		P value for trend
			Insufficiently Active	Met Guidelines	
Total Score	Mean Two-Year Change	-1.15	1.95	10.31	-
	Difference compared to Remained Inactive (95% CI)	Unadjusted Difference	3.10 (0.78, 5.43)	11.46 (5.29, 17.63)	<.001
		Adjusted Difference ^b	2.57 (0.30, 4.83)	10.15 (4.48, 15.81)	<.001
Instrumental Role	Mean Two-Year Change	-1.24	2.08	10.75	-
	Difference compared to Remained Inactive (95% CI)	Unadjusted Difference	3.32 (0.90, 5.74)	11.99 (5.58, 18.41)	<.001
		Adjusted Difference ^b	2.80 (0.43, 5.16)	10.46 (4.55, 16.37)	<.001
Management Role	Mean Two-Year Change	-0.46	0.96	4.43	-
	Difference compared to Remained Inactive (95% CI)	Unadjusted Difference	1.42 (-0.49, 3.33)	4.89 (-0.18, 9.96)	0.029
		Adjusted Difference ^b	1.11 (-0.78, 3.00)	5.36 (0.64, 10.09)	0.034

^aPositive change indicate improvement in disability status, negative change indicate worsening.

^b Adjusted differences estimated from multiple linear regression model controlling for: Socioeconomic factors (socioeconomics: age, live alone, sex, race, education, income), Health factors (comorbidity, Body Mass Index status, high depressive symptoms, smoking, Kellgren and Lawrence grade, Western Ontario and McMaster University OA Index pain score, knee symptoms, knee injury, lower extremity pain), baseline LLDI disability score

Table 3

Disability in LLDI Frequency Dimension: Mean Two-year Change^a, Difference in Change Related to a Transition to More Active Status Versus Remaining Inactive (n=545), 2008–2012.

LLDI Frequency Dimension		Year 2 Activity Status Among Baseline Inactive Adults			
		Remained Inactive	More Active		P value for trend
			Insufficiently Active	Met Guidelines	
Total Score	Mean Two-Year Change	−0.46	−0.41	2.68	–
	Difference compared to Remained Inactive (95% CI)	Reference	0.05 (−0.74, 0.84)	3.14 (1.05, 5.23)	0.084
				3.13 (1.07, 5.18)	
Social Role	Mean Two-Year Change	−0.58	−0.83	2.74	–
	Difference compared to Remained Inactive (95% CI)	Reference	−0.26 (−1.27, 0.76)	3.31 (0.62, 6.00)	0.344
				3.19 (0.50, 5.89)	
Personal Role	Mean Two-Year Change	−1.07	0.80	3.75	–
	Difference compared to Remained Inactive (95% CI)	Reference	1.87 (−0.38, 4.13)	4.82 (−1.16, 10.81)	0.032
				7.22 (1.82, 12.61)	

^aPositive change indicate improvement in disability status, negative change indicate worsening.

^bCovariates in multiple linear regression models: Socioeconomic factors (socioeconomics: age, live alone, sex, race, education, income), Health factors (comorbidity, Body Mass Index status, high depressive symptoms, smoking, Kellgren and Lawrence grade, Western Ontario and McMaster University OA Index pain score, knee symptoms, knee injury, lower extremity pain), baseline LLDI disability frequency score