ORIGINAL ARTICLE

Moving to Maintain Function in Knee Osteoarthritis: Evidence From the Osteoarthritis Initiative

Dorothy D. Dunlop, PhD, Pamela Semanik, PhD, APN, Jing Song, MS, Leena Sharma, MD, Michael Nevitt, PhD, Rebecca Jackson, MD, W. Jerry Mysiw, MD, Rowland W. Chang, MD, MPH, for the Osteoarthritis Initiative Investigators

ABSTRACT. Dunlop DD, Semanik P, Song J, Sharma L, Nevitt M, Jackson R, Mysiw WJ, Chang RW, for the Osteoarthritis Initiative Investigators. Moving to maintain function in knee osteoarthritis: evidence from the Osteoarthritis Initiative. Arch Phys Med Rehabil 2010;91:714-21.

Objectives: To investigate the association between baseline physical activity and 1-year functional performance in adults with knee osteoarthritis (OA).

Design: Prospective cohort study of knee OA development and progression with 1-year follow-up.

Setting: Community.

Participants: Osteoarthritis Initiative public data on adults with knee OA (n=2274; age, 45–79y) who participated in functional performance assessments (timed 20-m walk and chair stand test) at baseline and 1-year follow-up.

Interventions: Not applicable.

Main Outcome Measure: A good 1-year performance outcome (separately defined for walk time and chair stand measures) was improvement from baseline quintile or maintenance in the best quintile.

Results: Almost 2 in 5 persons with radiographic knee OA improved or maintained high performance at 1 year. Physical activity measured by the Physical Activity Scale for the Elderly (PASE) was significantly associated with good walk rate and chair stand outcomes (odds ratio per 40 units PASE [95% confidence interval]=1.13 [1.13, 1.17] and 1.10 [1.05, 1.15], respectively), as were participation in sports/recreational activities (1.45 [1.23, 1.71] and 1.29 [1.09, 1.51], respectively) and lifestyle activities (1.11 [1.06, 1.16] and 1.09 [1.04, 1.14], respectively). An independent protective relationship for these physical activity measures approached significance after adjusting for sociodemographic and health factors. Older adults reported the least baseline physical activity and least frequent good 1-year outcomes.

Conclusions: These findings support public health recommendations to be physically active in order to preserve function for persons with knee OA. Physical activity messages should specifically target older adults whose low activity levels may jeopardize their ability to maintain functional performance.

Key Words: Osteoarthritis; Rehabilitation.

ARTHRITIS IS A COSTLY disease to society and to the person. Costs as a result of arthritis exceed $128 billion annually.[1] More than 46 million Americans (more than 1 in every 5 adults) report arthritis and other rheumatic conditions, and 19 million (1 in every 11 adults) report arthritis-attributable activity limitations.[2] Knee osteoarthritis is a highly prevalent condition in adults and is a leading cause of arthritis-related activity limitations.[3,4]

While some reports examine risk factors predicting functional decline, the research on maintaining high physical function or improving physical function among adults in the general population is limited.[5-10] Among persons with knee osteoarthritis, such studies are particularly scarce. Physical activity is widely recognized to be beneficial to cardiovascular health in the general population and is an attractive mutable risk factor to improve health outcomes for persons with arthritis.[11] Recently released updated physical activity guidelines include a section specifically for persons with osteoarthritis.[12]

This article examines factors that may preserve or improve function over time for persons with knee OA. A good outcome is defined as maintaining high function or improving functional performance over 1 year. Longitudinal data from the OAI that included 2274 persons with radiographic knee osteoarthritis at the baseline interview were used to answer the following research questions related to functional performance 1 year later:

1. What proportion demonstrated good 1-year outcomes (ie, improved performance by at least 1 quintile compared with baseline or maintenance in the highest performance quintile)?

List of Abbreviations

BMI	body mass index
CESD	Center for Epidemiological Studies Depression
CI	confidence interval
OA	osteoarthritis
OAI	Osteoarthritis Initiative
OR	odds ratio
PASE	Physical Activity Scale for the Elderly
WOMAC	Western Ontario and McMaster University Osteoarthritis Index

From Northwestern University Feinberg School of Medicine (Chang, Dunlop, Song, Sharma) and the Rehabilitation Institute of Chicago (Chang, Semanik), Chicago, IL; Ohio State University, Columbus, OH (Jackson, Mysiw); University of California, San Francisco, CA (Nevitt).

Presented to the American College of Rheumatology, 2008 Annual Scientific Meeting, San Francisco, CA, October 26, 2008.

Supported in part by the National Institute for Arthritis and Musculoskeletal Diseases (grant nos. P60-AR48098, R01-AR055287, R01-AR054155) and the Arthritis Foundation. The Osteoarthritis Initiative (OAI) is a public-private partnership comprised of 5 contracts (N01-AR-2-2258, N01-AR-2-2259, N01-AR-2-2260, N01-AR-2-2261, N01-AR-2-2262) funded by the National Institutes of Health, a branch of the Department of Health and Human Services, and conducted by the OAI Study Investigators. Private funding partners include Merck Research Laboratories, Novartis Pharmaceuticals Corp, GlaxoSmithKline, and Pfizer, Inc. Private sector funding for the OAI is managed by the Foundation for the National Institutes of Health.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Correspondence to Dorothy D. Dunlop, PhD, Institute for Health Services Research, Feinberg School of Medicine, Northwestern University, 750 N Lake Shore Dr, Chicago, IL 60611, e-mail: *ddunlop@northwestern.edu.* Reprints are not available from the author.

0003-9993/10/9105-00950$36.00/0
doi:10.1016/j.apmr.2010.01.015

2. Is there a type of physical activity that is particularly associated with good outcomes?
3. What are the significant sociodemographic and health determinants of good outcomes?

METHODS

Data and Study Sample

This study analyzed public data from the OAI, a prospective study of the development and progression of knee OA in men and women age 45 to 79 years at enrollment. Annual OAI interviews began in 2004 and continue at 4 clinical sites: Baltimore, MD; Columbus, OH; Pittsburgh, PA; and Pawtucket, RI. The baseline OAI visit identified 2678 participants with radiographic knee OA (ie, radiographic evidence based on Kellgren-Lawrence grade of 2 or more calculated from separate scores for osteophytes and joint space narrowing in a knee) in 1 or both knees, of whom 1403 had knee symptoms (pain, aching, and/or stiffness on most days of a month during the past year) from the total OAI enrollment of 4796 persons. Excluded were persons with bilateral total knee replacement, planned knee replacement, inflammatory arthritis, contraindications to 3.0 tesla magnetic resonance imaging (men>130kg and women>114kg), comorbid conditions likely to interfere with participation, plans to relocate, and other clinical trial participation, and persons who were nonambulatory. To investigate factors related to good functional performance over 1 year, we merged public data from OAI baseline (OA1 public data version) and 1-year (V1.2.1) interviews. A total of 2274 persons with baseline radiographic knee OA who participated in functional performance assessments (timed 20-m walk and chair stand test) at both interviews composed the analysis sample. An additional 8 decedents, 163 not returning for the OAI 1-year evaluation, 69 with incomplete baseline data, and 164 persons with incomplete 1-year performance data were excluded from analysis.

Functional Performance Outcome From Baseline to 1 Year

Functional performance was assessed by a timed 20-m walk and a chair stand test. The timed 20-m walk is a standard outcome measure for osteoarthritis.[13] Walk rates based on 2 trials measured in meters per minute from the entire baseline OAI radiographic knee OA cohort were classified by quintile from worst to best performance: first quintile, Q1 less than or equal to 67.4; second quintile, Q2 67.4 to 74.9; third quintile, Q3 74.9 to 80.9; fourth quintile, Q4 80.9 to 87.8; and fifth quintile, Q5 greater than 88. Walk rates from the baseline and 1-year evaluations were categorized into one of these quintiles.

Chair stand testing (time required for 5 repetitions to rise from a chair and sit down) depends heavily on knee function and assesses strength, balance, coordination, and flexibility. The OAI chair stand protocol standardizes the chair, its position, the stopwatch, floor surface footwear, arm position (crossed over the chest), and scripted instructions. Chair stand rates based on 2 trials measured in repetitions per minute from the entire baseline OAI radiographic knee OA cohort were classified by quintile from worst to best performance: first quintile, Q1 less than or equal to 21.0; second quintile, Q2 21.0 to 25.8; third quintile, Q3 25.8 to 30.0; fourth quintile, Q4 30.0 to 35.4; fifth quintile, Q5 greater than 35.4. Chair stand rates from the baseline and 1-year evaluations were categorized into one of these quintiles.

The baseline to 1-year functional experience was characterized separately for each performance test using a quintile grid shown in figure 1. This approach captures practical, meaningful changes in functional performance over time in osteoarthritis populations.[14-16] Good outcomes based on improved/high performance are defined by transition to an improved functional performance quintile over 1 year (ie, moving from Q1 to Q4 at baseline to a better quintile at the 1-year evaluation) or maintaining function in the best performance quintile (ie, Q5 at both baseline and 1-year evaluations) as shown by the shaded portion of figure 1. Boxes that are not shaded represent a poor functional performance outcome.

Physical Activity

Self-reported physical activity was measured using the PASE.[17] The self-administered 26-question PASE assesses a broad spectrum of activities during the previous 7-day period.[18] The calculated PASE score has demonstrated reliability and validity.[19,20] PASE scores increase with greater moderate intensity activity time. For the purpose of analysis, we divided the total PASE score into portions corresponding to questions that assess lifestyle activity (housework, home repair, gardening, yard work, paid or volunteer work-related activity), purposeful exercise/sports (light, moderate, strenuous sport/recreation; muscular strength and endurance), and walking outdoors (outside the home or in the yard for any reason).

	Quintile Group at 12 month follow-up				
Quintile Group at baseline	Q1 Worst	Q2	Q3	Q4	Q5 Best
Q1 (Worst)					
Q2			*GOOD	OUTCOMES	
Q3					
Q4	POOR	OUTCOMES			
Q5					
Walk rate quintiles (meters/minute) †	≤67.4	67.4–74.9	74.9–80.9	80.9–87.8	>87.8
Chair stand quintiles (repetitions/minute) ‡	≤21	21–25.8	25.8–30	30–35.4	>35.4

Fig 1. Good and poor functional performance outcomes from baseline to 1 year. *Good outcome: improved performance from Q1 to Q4 at baseline to higher quintile at 1-year evaluation or maintained performance in best Q5 quintile at both baseline and 1-year evaluation. †Walk rate quintiles based on all n=2664 baseline OAI participants with radiographic knee OA evaluated by timed 20-m walk test. ‡Chair stand quintiles based on all n=2667 baseline OAI participants with radiographic knee OA evaluated by chair stand test.

Covariates

Baseline sociodemographic factors included race, age, sex, marital status, and education. Individuals were classified as black, white, or other race based on self-report. Education was dichotomized as post–high school versus less education.

Knee health was assessed at baseline. The presence of knee symptoms was ascertained from a positive response to the question, "During the past 12 months, have you had pain, aching, or stiffness in or around either knee on most days for at least one month?" Disease severity for each knee was based on a Kellgren-Lawrence grade calculated by the OAI from the baseline scores for osteophyte and joint space narrowing as grade 1 (doubtful), possible osteophyte of doubtful significance or isolated mild-moderate joint space narrowing; grade 2 (minimal), definite osteophytes and unimpaired joint space or isolated severe joint space narrowing; grade 3 (moderate), definite osteophytes and moderate diminution of joint space; and grade 4 (severe), definite osteophytes, joint space greatly impaired. Self-reported knee pain was measured by a 5-point Likert scale from the WOMAC (Likert version, 3.1) modified to ask about the right and left knee symptoms separately[21] in the past 7 days. The WOMAC pain score range is 0 to 20; a higher number represents worse symptoms. Person-level scores were calculated from knee-specific scores (ie, disease severity grade and WOMAC pain score) using the maximum value of the 2 knees.

General health factors assessed included the self-report of hip pain, ankle pain, foot pain, current smoking, current alcohol consumption, comorbidity, high depressive symptoms, and BMI. The presence of comorbidity was ascertained from a Charlson index[22] score greater than 0. Evidence of high depressive symptoms was based on a score greater than or equal to 16 from the full 20-item CESD scale.[23] BMI was calculated from measured height and weight [weight (kg)/height $(m)^2$].

The protocol for the OAI was approved by the institutional review boards at each of the participating sites.

Statistical Analysis

Analyses were restricted to individuals who participated in both the baseline and 1-year OAI visits. Descriptive statistics characterized the baseline sample by physical activity (above or below median baseline PASE score). Logistic regression evaluated the relationship between baseline physical activity and 1-year performance outcomes; those results are reported as ORs. Physical activity score ORs are expressed per 40 units; this increment equals 0.5 SD in the PASE score to reflect a potentially meaningful change in physical activity as measured by PASE. Recognizing that systematic differences between persons included (n=2274) and excluded (n=404) from the analysis sample could influence our findings, we performed weighted analyses recommended by Hogan,[24] Robins,[25] and colleagues. Results and statistical significance were very similar for weighted and unweighted analyses. For simplicity, unweighted analyses were reported. All analyses were performed using SAS software version 9.2.

RESULTS

A total of 2274 persons with radiographic knee OA (age, 45–79y) participated in performance tests at the baseline and 1-year OAI evaluations. In this sample, 60% had bilateral involvement, and half had knee symptoms based on the report of pain, aching, or stiffness on most days in at least one month during the previous year. This analytic sample was predominantly white (81.6%) and female (56.8%), and the average baseline age was 62.5 years. The group of 404 persons with radiographic knee OA who did not return for the 1-year evaluation or had incomplete data were similar in age (mean, 62.0 vs 62.5y) but were more likely to be black (34% vs 17%) or female (67% vs 57%) than those included in the analysis sample.

Baseline physical activity measured by the total PASE score ranged from 0 to 465, with a mean ± SD of 157±79, indicating this radiographic knee OA cohort had substantial variability in physical activity. The total PASE was divided into lifestyle activity, purposeful exercise/sports, and walking outdoors which had mean ± SD values of 130±72, 12±21, and 14±17, respectively.

For descriptive purposes, this radiographic knee OA cohort was stratified by baseline levels of physical activity (table 1). Persons with baseline PASE scores above the median tended to be younger and male, reported more education, and were less likely to report comorbidity or prior knee injuries compared with their less active counterparts. There were no notable differences in disease severity or knee pain related to physical activity.

The cross-sectional relationship between baseline physical activity levels and functional performance for this knee OA cohort is shown in figure 2. Average physical activity measured by the total PASE score increased with membership in higher (ie, better) performance quintiles for both walk rate and chair stand rate. Each PASE score bar is divided into those portions contributed by lifestyle activities, exercise/sports, and walking outdoors questions. It is notable that lifestyle activities contributed the largest portion to the total PASE score. The portion of the total PASE score contributed by walking outdoors is relatively constant across all performance quintiles. Increased physical activity among persons in high performing quintiles is largely a result of more participation in lifestyle and exercise/sports activities.

Analyses addressing the first research question examined the frequency of good functional performance outcomes. The average cohort performance was unchanged at baseline and 12 months (at both evaluations walk rate averaged 78m/min; chair stand rate averaged 28 repetitions/min). However, many individuals demonstrated improvements in performance or maintenance in the highest performance quintile (table 2). More than 1 out of 4 persons improved performance (ie, moved to a better quintile compared with baseline). Another 11% to 15% remained in the best performing quintile. Together, approximately 40% of this knee OA cohort had good (improved/high) outcomes after 1 year.

Analyses to address the second research question examined the relationship of the total PASE score and that of the partitioned PASE scores (exercise/sport, lifestyle activities, walking outdoors) with good functional performance outcomes (table 3). Good outcomes were significantly related to higher values of the total PASE score for walk rate (OR/40 units=1.13) and chair stand performance (OR/40 units=1.10). Separate analyses entered the partitioned PASE scores into logistic regression models in place of the total score. Lifestyle activity had a significant beneficial relationship to subsequent high/maintained performance (OR/40 units: walk rate=1.11; chair stand rate=1.09) as did purposeful exercise/sports (OR/40 units: walk rate=1.45; chair stand rate=1.29). Walking outdoors as ascertained by PASE was not significantly related to good outcomes (OR/40 units: walk rate=.99; chair stand=1.00). These analyses demonstrated positive relationships between baseline physical activity and good performance outcomes 1 year later; that relationship was strongest for exercise/sports, followed by lifestyle activities. Further analyses that controlled for sociodemographics and health factors demonstrated a positive but

Table 1: Baseline Characteristics of Persons (n=2274) With Radiographic Knee OA Participating in OAI Baseline and 1-Year Evaluations

Baseline Characteristics	Overall (n=2274)	PASE score<median (147) (n=1132)	PASE score≥median (147) (n=1142)
OAI radiograph OA sample	100	100	100
Sociodemographics			
Age (y)	62.5±9.1	65.1±8.9	59.9±8.5
Race			
White	81.2	80.4	82.1
Black	16.6	17.6	15.6
Other	2.2	2.0	2.4
Sex, female	57.0	62.5	51.4
Married, yes	66.9	64.3	69.5
Education, post–high school	83.5	80.5	86.4
Health factors			
Knee health			
Knee OA severity			
OA grade 2	31.5	30.7	32.3
OA grade 3	47.7	47.5	47.9
OA grade 4	20.8	21.8	19.8
Knee symptoms: report of pain, aching, or stiffness most days for at least one month during the past 12mo	50.0	47.7	52.4
Knee pain severity*	3.8±3.8	3.8±3.8	3.8±3.8
Prior knee injury	45.4	40.7	50.1
General health			
Any hip pain	55.2	56.4	54.0
Any ankle pain	10.7	11.2	10.2
Any foot pain	11.4	11.3	11.5
Charlson index>0	25.6	28.6	22.7
High depressive symptoms†	9.6	9.9	9.3
BMI	29.4±4.8	29.6±4.9	29.3±4.7
Current smoker	5.6	5.1	6.1
Alcohol use, 0 drinks/d	18.7	21.1	16.3
<1 drinks/d	36.9	37.2	36.7
1+ drinks/d	44.4	41.7	47.0

NOTE. Values are percentages or mean ± SD.
*WOMAC pain score in the more symptomatic (painful) knee.
†CESD>16.

attenuated relationship between physical activity and good outcomes. In sensitivity analyses (not shown) that additionally controlled for 1-year changes from baseline in PASE and WOMAC pain; the OR of baseline PASE on good outcomes was identical to the table 4 results.

Analyses to address the third research question investigated the relationship of baseline sociodemographic and health factors to subsequent improved/high performance controlling for physical activity (see table 4 for multiple logistic regression results). Sociodemographic factors that significantly increased the odds of good outcomes 1 year later adjusting for all factors were higher education (OR: walk rate=1.45; chair stand=1.66) and being married (OR: walk rate=1.32), while the odds of good outcomes were significantly decreased by older age (OR/5 years: walk rate=.88; chair stand=.90) and female sex (OR: walk rate=.70). Health factors that significantly decreased the adjusted odds of good outcomes were greater BMI (OR/unit: walk rate=.96) and greater WOMAC knee pain (OR/unit: chair stand=.94). It is notable that disease severity based on radiographic evidence was not associated with subsequent good performance outcomes.

The strong inverse relationship of older age to less frequent good outcomes and the attenuated relationship of physical activity with good outcomes after accounting for sociodemographic factors motivated further analyses. We examined the frequency of good outcomes in persons with high (above the median PASE score) versus low physical activity levels stratified on age group (45–54, 55–64, 65–75y). The stratified ORs of good walk rate outcomes for persons in the high versus lower physical activity groups ranged from 1.01 to 1.14, and the stratified odds of good chair stand outcomes ranged from 1.02 to 1.07 with adjustment for other sociodemographic and health factors. These analyses showed that within each age group, good outcomes were most frequent among those persons with higher levels of baseline physical activity compared with their less active counterparts.

Further analyses examined for the potential of an effect modification related to knee symptoms by adding an interaction term between knee symptoms and physical activity to our model. That interaction term was not significant, which indicates that these findings do not depend on the presence or absence of knee symptoms.

DISCUSSION

This article adds to the literature by examining factors that may preserve function over time for persons with knee OA. This study provides evidence of the positive benefit from physical activity in relation to good outcomes in functional

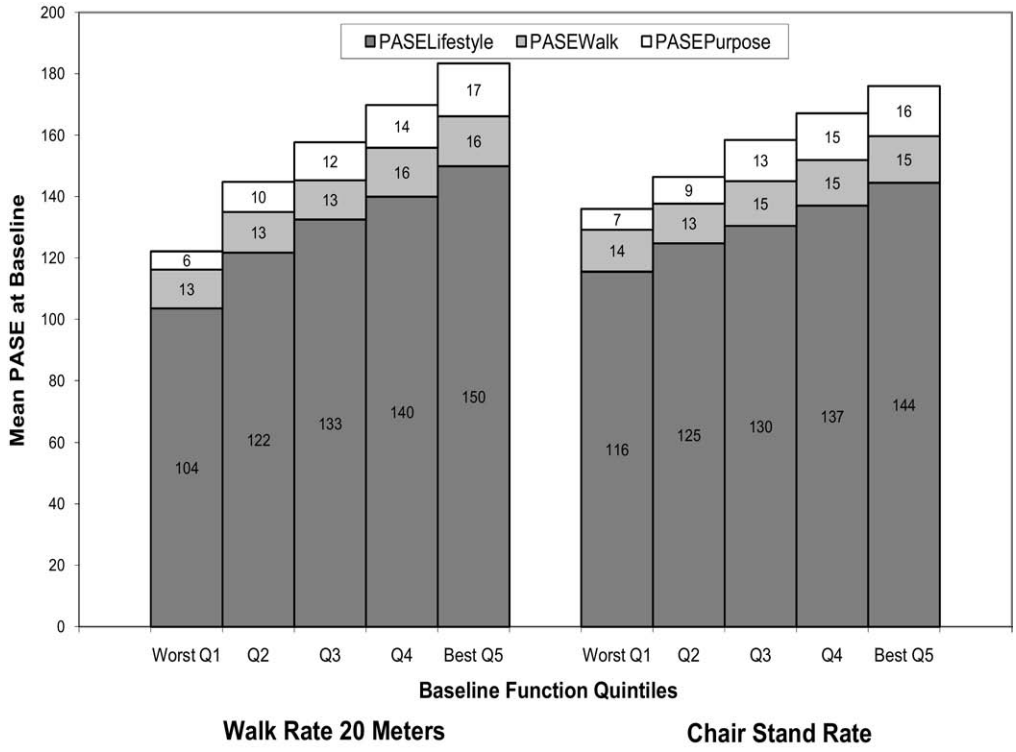

Fig 2. Baseline relationship between physical activity and function (n=2274).

performance over 1 year from a cohort of 2274 persons with radiographic knee OA. Almost 1 in 4 persons in this cohort improved functional performance at 1 year compared with baseline. Among persons performing in top quintiles at baseline on the timed 20-m walk or chair stand tests, over half maintained that high function 1 year later. Greater physical activity measured by the total PASE was significantly associated with improved/high performance over 1 year. Physical activity from lifestyle activities and exercise/sports had strong associations with subsequent improved/high performance.

Our findings that exercise/sports activities (those performed to achieve a training effect) are related to subsequent good performance outcomes are consistent with other studies. Randomized controlled trials demonstrate that exercise, muscle strengthening regimens, and aquatic therapy improve performance in walking, stair stepping, and getting in/out of a car.[26-29] However, the value of lifestyle activities are not addressed in those studies. Recent interest in lifestyle activity is spawned by poor adherence rates[26,30-33] to structured exercise regimens, which reduces potential benefit.[34,35] Our findings suggest that lifestyle activities are related to subsequent improved/high performance among persons with knee OA.

Sociodemographic and health factors attenuated (often to nonsignificance) the positive relationship of physical activity to good outcomes in walk rate and chair stand performance. Although sociodemographic factors are recognized confounders, some health factors may be on the causal pathway. For example, physical activity is beneficial to reduce pain, depressive symptoms, and body weight. These health factors also influence function and may partially be a result of the beneficial effect of physical activity on function. In addition, more precise objective measures of physical activity may demonstrate stronger relationships in the presence of confounders.

Predictors of good functional outcomes in persons with radiographic knee OA are in harmony with other studies in the general population. Sociodemographic factors related to good functional outcomes in this osteoarthritis cohort were younger age, more education, and male sex, consistent with literature on older adults.[8,10,36,37] Health factors in the present study that were significantly detrimental to good outcomes were knee pain and greater BMI. Pain in the leg or knees is also negatively associated with improved function in the general population.[6,8] Greater BMI has been identified as both protective[10] and detrimental[5,9] to good function in the general population. Our finding that the severity of knee OA did not affect subsequent improved/high performance is consistent with a knee pain study in older adults that concluded the severity of radiographic knee OA had limited value to predict which persons experienced progressive functional difficulties.[16]

The value of lifestyle activities and exercise/sports to improve or maintain high function is a valuable message for clinicians to convey to their patients with knee OA. Advice from a health care provider can positively influence the physical activity behavior of patients.[38] However, advice to exercise

Table 2: Frequency of 1-Year Good Functional Performance Outcomes, n=2274 With Radiographic Knee OA

Functional Performance Assessment	Good Outcome Based on Maintaining Top Quintile Performance Level	Good Outcome Based on Improved Performance by at Least 1 Quintile	Total Good Outcomes
20-m walk	14.6%	28.4%	43.0%
Chair stand	11.4%	28.4%	39.8%

Table 3: Baseline Physical Activity ORs in Relation to Good Walk Rate Outcomes and Good Chair Stand Performance Outcomes Over 1 Year*

Adjustment Factors	Good Walk Rate Outcome Over 1 Year (n=2274)				Good Chair Stand Outcome Over 1 Year (n=2274)			
	PASE Total Activity OR (per 40 Units†)	PASE Lifestyle Activity OR (per 40 Units)	PASE Exercise/Sports Activity OR (per 40 Units)	PASE Walking Activity OR (per 40 Units)	PASE Total Activity OR (per 40 Units)	PASE Lifestyle Activity OR (per 40 Units)	PASE Exercise/Sports Activity OR (per 40 Units)	PASE Walking Activity OR (per 40 Units)
Unadjusted	**1.13 (1.08–1.17)***	**1.11 (1.06–1.16)**	**1.45 (1.23–1.71)**	0.99 (0.81–1.20)	**1.10 (1.05–1.15)**	**1.09 (1.04–1.14)**	**1.29 (1.09–1.51)**	1.00 (0.82–1.22)
Sociodemographic‡	**1.05 (1.01–1.10)**	1.04 (0.99–1.09)	**1.27 (1.07–1.51)**	1.03 (0.84–1.26)	1.04 (0.99–1.09)	1.03 (0.97–1.08)	1.15 (0.97–1.36)	1.05 (0.86–1.29)
Sociodemographic‡ + health factors§	1.05 (1.00–1.10)	1.04 (0.98–1.09)	**1.22 (1.03–1.44)**	1.00 (0.82–1.23)	1.04 (0.99–1.09)	1.03 (0.98–1.08)	1.12 (0.94–1.32)	1.09 (0.88–1.34)

*Boldface values indicate statistical significance based on 95% OR CIs that exclude 1.
†An OR per 40 units is given to reflect a potentially meaningful change of 0.5 SDs in the PASE score.
‡Sociodemographic factors: race, age, sex, marital status, and education.
§Health factors: knee OA severity, knee symptoms, knee pain severity, hip pain, ankle pain, foot pain, presence of comorbidity, presence of high depressive symptoms, BMI, current smoking, and current alcohol consumption.

Table 4: Multivariate ORs for Good Outcomes in Walk Rate and Chair Stand Performance From Baseline to 1 Year (n=2274)*

Baseline Characteristics	OR for Good Outcome: 20-m Walk Rate OR (95% CI)	Chair Stand Performance OR (95% CI)
Physical activity		
Total PASE (per 40-unit increase)	1.05 (1.00–1.10)	1.04 (0.99–1.09)
Sociodemographics		
Age per 5y	**0.88 (0.83–0.93)**	**0.90 (0.85–0.95)**
Race		
White/other	Reference	Reference
Black	1.14 (0.87–1.49)	0.92 (0.70–1.21)
Female	**0.70 (0.58–0.84)**	0.83 (0.69–1.01)
Married	**1.32 (1.08–1.62)**	0.99 (0.81–1.21)
Education (y)		
0-12	Reference	Reference
13+	**1.45 (1.13–1.86)**	**1.66 (1.28–2.16)**
Health factors		
Knee health		
Knee OA severity		
OA grade 2	Reference	Reference
OA grade 3	0.91 (0.75–1.11)	1.00 (0.82–1.22)
OA grade 4	0.79 (0.61–1.02)	0.94 (0.72–1.22)
Knee symptoms	0.95 (0.78–1.17)	1.10 (0.90–1.34)
Knee pain severity†	0.98 (0.95–1.00)	**0.94 (0.91–0.97)**
Prior knee injury	1.09 (0.91–1.31)	0.91 (0.76–1.09)
General health		
Any hip pain	0.92 (0.77–1.11)	0.91 (0.76–1.08)
Any ankle pain	1.16 (0.86–1.57)	0.80 (0.58–1.08)
Any foot pain	0.82 (0.62–1.10)	0.85 (0.63–1.14)
Charlson index>0	0.84 (0.68–1.03)	0.96 (0.78–1.18)
High depressive symptoms‡	0.89 (0.65–1.21)	0.91 (0.66–1.25)
BMI per unit	**0.96 (0.94–0.98)**	0.99 (0.97–1.01)
Current smoker	0.78 (0.53–1.15)	1.23 (0.84–1.80)
Uses alcohol	0.92 (0.73–1.16)	1.06 (0.84–1.34)

*Boldface values indicate statistical significance based on 95% OR CIs that exclude 1.
†Per unit of WOMAC pain score in the more symptomatic (painful) knee.
‡CESD>16.

may not resonate with some persons having knee OA because of a lack of resources or limited interest in exercise regimens. This study suggests that a broad spectrum of activities is beneficial. The positive relationship of lifestyle activities and exercise to sustained or improved functional performance strengthens the appeal of a clinician's advice.

Findings from this study have important public health implications. First, the substantial frequency of subsequent improved performance is an encouraging indication that functional decline is reversible in adults with knee OA. Second, results demonstrating a relationship of physical activity to good subsequent performance strengthen the arthritis public health message from the Centers for Disease Control and Prevention to keep moving to preserve function.[39] Finally, this study indicates that an important target for this public health message is older adults with arthritis. Low levels of baseline physical activity were common among older persons with knee OA. In turn, older persons with lower levels of physical activity were less likely to have good outcomes in functional performance. Taken together, this information spotlights older adults with knee OA as an important target for the message to keep moving.

Study Limitations

Some limitations related to these findings should be considered. Our physical activity measure is based on self-report. However, the validity of PASE is established for adults with knee pain and physical disability.[20] While the PASE score was not designed to be partitioned, in general our findings related to exercise/sports, lifestyle, and walking portions of the PASE are consonant with other physical activity studies in adults, including persons with arthritis.[14,26-29,40] The weak relationship between walking outdoors and good performance outcomes may be related to the aggregation of various walking intensities within the single posed PASE walking question. We were unable to adjust for OA grade at follow-up. However, the proportion with worsening of grade by 1 year is likely to be extremely low.[41] The generalizability of this cohort merits consideration. While all persons in this analysis sample had radiographic disease, some did not have knee symptoms. However, there was no evidence of an effect modification of these results based on knee symptoms. Also, causation cannot be inferred from these observational data.

CONCLUSIONS

Findings based on over 2200 persons with radiographic knee OA support a positive relationship of physical activity with improved/high performance over 1 year. These findings undergird clinical advice to patients to engage in physical activity including lifestyle activity and exercise to sustain or improve their functional performance. Public health physical activity messages should specifically target older adults whose low activity levels may jeopardize their functional performance, a critical component of independent community living.

Acknowledgments. We thank Leilani Lacson, BS, for her diligent search of the literature. This article has received the approval of the OAI Publications Committee based on a review of its scientific content and data interpretation.

References

1. Yelin E, Murphy L, Cisternas MG, Foreman AJ, Pasta DJ, Helmick CG. Medical care expenditures and earnings losses among persons with arthritis and other rheumatic conditions in 2003, and comparisons with 1997. Arthritis Rheum 2007;56:1397-407.
2. Hootman JM, Helmick CG. Projections of US prevalence of arthritis and associated activity limitations. Arthritis Rheum 2006; 54:226-9.
3. Dillon CF, Rasch EK, Gu Q, Hirsch R. Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. J Rheumatol 2006;33:2271-9.
4. Felson DT, Lawrence RC, Dieppe PA, et al. Osteoarthritis: new insights, part 1: the disease and its risk factors. Ann Intern Med 2000;133:635-46.
5. Lee Y, Park KH. Health practices that predict recovery from functional limitations in older adults. Am J Prev Med 2006;31:25-31.
6. Miller RR, Zhang Y, Silliman RA, et al. Effect of medical conditions on improvement in self-reported and observed functional performance of elders. J Am Geriatr Soc 2004;52:217-23.
7. Clark DO, Stump TE, Hui SL, Wolinsky FD. Predictors of mobility and basic ADL difficulty among adults aged 70 years and older 4. J Aging Health 1998;10:422-40.
8. Guralnik JM, LaCroix AZ, Abbott RD, et al. Maintaining mobility in late life, I: demographic characteristics and chronic conditions. Am J Epidemiol 1993;137:845-57.
9. LaCroix AZ, Guralnik JM, Berkman LF, Wallace RB, Satterfield S. Maintaining mobility in late life. II. Smoking, alcohol consumption, physical activity, and body mass index. Am J Epidemiol 1993;137:858-69.
10. Feinglass J, Song J, Manheim LM, Semanik P, Chang RW, Dunlop DD. Correlates of improvement in walking ability in older persons in the United States. Am J Public Health 2009;99:533-9.
11. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1435-45.
12. Physical Activity Guidelines Committee. 2008 Physical activity guidelines for Americans. Washington, DC: Department of Health and Human Services; 2008.
13. Altman R, Brandt K, Hochberg M, et al. Design and conduct of clinical trials in patients with osteoarthritis: recommendations from a task force of the Osteoarthritis Research Society: results from a workshop. Osteoarthritis Cartilage 1996;4:217-43.
14. Sharma L, Cahue S, Song J, Hayes K, Pai YC, Dunlop D. Physical functioning over three years in knee osteoarthritis: role of psychosocial, local mechanical, and neuromuscular factors. Arthritis Rheum 2003;48:3359-70.
15. Mallen CD, Peat G, Thomas E, Lacey R, Croft P. Predicting poor functional outcome in community-dwelling older adults with knee pain: prognostic value of generic indicators. Ann Rheum Dis 2007;66:1456-61.
16. Thomas E, Peat G, Mallen C, et al. Predicting the course of functional limitation among older adults with knee pain: do local signs, symptoms and radiographs add anything to general indicators? Ann Rheum Dis 2008;67:1390-8.
17. Washburn RA, Smith KW, Jette AM, Janney CA. The Physical Activity Scale for the Elderly (PASE): development and evaluation 2. J Clin Epidemiol 1993;46:153-62.
18. Washburn RA, McAuley E, Katula J, Mihalko SL, Boileau RA. The physical activity scale for the elderly (PASE): evidence for validity. J Clin Epidemiol 1999;52:643-51.
19. Dinger MK, Oman RF, Taylor EL, Vesely SK, Able J. Stability and convergent validity of the Physical Activity Scale for the Elderly (PASE). J Sports Med Phys Fitness 2004;44:186-92.
20. Martin KA, Rejeski WJ, Miller ME, James MK, Ettinger WH Jr, Messier SP. Validation of the PASE in older adults with knee pain and physical disability. Med Sci Sports Exerc 1999;31:627-33.
21. McGrory BJ, Harris WH. Can the Western Ontario and McMaster Universities (WOMAC) osteoarthritis index be used to evaluate different hip joints in the same patient? J Arthroplasty 1996;11:841-4.
22. Katz JN, Chang LC, Sangha O, Fossel AH, Bates DW. Can comorbidity be measured by questionnaire rather than medical record review? Med Care 1996;34:73-84.
23. Pandya R, Metz L, Patten SB. Predictive value of the CES-D in detecting depression among candidates for disease-modifying multiple sclerosis treatment. Psychosomatics 2005;46:131-4.
24. Hogan JW, Roy J, Korkontzelou C. Handling drop-out in longitudinal studies. Stat Med 2004;23:1455-97.
25. Robins JM, Rotnitzky A, Zhao LP. Analysis of semiparametric regression models for repeated outcomes in the presence of missing data. J Am Stat Assoc 1995;90:106-21.
26. Ettinger WH Jr, Burns R, Messier SP, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST). JAMA 1997;277:25-31.
27. Focht BC, Rejeski WJ, Ambrosius WT, Katula JA, Messier SP. Exercise, self-efficacy, and mobility performance in overweight and obese older adults with knee osteoarthritis. Arthritis Rheum 2005;53:659-65.
28. Topp R, Woolley S, Hornyak J 3rd, Khuder S, Kahaleh B. The effect of dynamic versus isometric resistance training on pain and

functioning among adults with osteoarthritis of the knee. Arch Phys Med Rehabil 2002;83:1187-95.
29. Bartels EM, Lund H, Hagen KB, Dagfinrud H, Christensen R, Danneskiold-Samsoe B. Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database Syst Rev 2007(4): CD005523.
30. Bock BC, Marcus BH, Pinto BM, Forsyth LH. Maintenance of physical activity following an individualized motivationally tailored intervention. Ann Behav Med 2001;23:79-87.
31. Dexter PA. Joint exercises in elderly persons with symptomatic osteoarthritis of the hip or knee. Performance patterns, medical support patterns, and the relationship between exercising and medical care. Arthritis Care Res 1992;5:36-41.
32. Burton LC, Shapiro S, German PS. Determinants of physical activity initiation and maintenance among community-dwelling older persons. Prev Med 1999;29:422-30.
33. Belza B, Topolski T, Kinne S, Patrick DL, Ramsey SD. Does adherence make a difference? Results from a community-based aquatic exercise program. Nurs Res 2002;51:285-91.
34. Pisters MF, Veenhof C, van Meeteren NL, et al. Long-term effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: a systematic review. Arthritis Rheum 2007;57: 1245-53.
35. van Gool CH, Penninx BW, Kempen GI, et al. Effects of exercise adherence on physical function among overweight older adults with knee osteoarthritis. Arthritis Rheum 2005;53:24-32.
36. Clark DO, Stump TE, Wolinsky FD. Predictors of onset of and recovery from mobility difficulty among adults aged 51-61 years. Am J Epidemiol 1998;148:63-71.
37. Mendes de Leon CF, Beckett LA, Fillenbaum GG, et al. Black-white differences in risk of becoming disabled and recovering from disability in old age: a longitudinal analysis of two EPESE populations. Am J Epidemiol 1997;145:488-97.
38. Van Sluijs EM, Van Poppel MN, Twisk JW, Brug J, Van Mechelen W. The positive effect on determinants of physical activity of a tailored, general practice-based physical activity intervention. Health Educ Res 2005;20:345-56.
39. National Center for Chronic Disease Prevention and Health Promotion. Arthritis basics. 2009. Available at: http://www.cdc.gov/arthritis/arthritis/key.htm. Accessed March 25, 2009.
40. Leaf DA, Reuben DB. "Lifestyle" interventions for promoting physical activity: a kilocalorie expenditure-based home feasibility study. Am J Med Sci 1996;312:68-75.
41. Emrani PS, Katz JN, Kessler CL, et al. Joint space narrowing and Kellgren-Lawrence progression in knee osteoarthritis: an analytic literature synthesis. Osteoarthr Cartil 2008;16:873-82.