2017-05-15

Change in Physical Activity and Sitting Time After Myocardial Infarction and Mortality Among Postmenopausal Women in the Women's Health Initiative-Observational Study

Anna M. Gorczyca
The University of Kansas Medical Center

Et al.

ORIGINAL RESEARCH

Change in Physical Activity and Sitting Time After Myocardial Infarction and Mortality Among Postmenopausal Women in the Women's Health Initiative-Observational Study

Anna M. Gorczyca, PhD; Charles B. Eaton, MD; Michael J. LaMonte, PhD; JoAnn E. Manson, MD, DrPH; Jeanne D. Johnston, PhD; Aurelian Bidulescu, MD, PhD; Molly E. Waring, PhD; Todd Manini, PhD; Lisa W. Martin, MD; Marcia L. Stefanick, PhD; Ka He, MD, ScD; Andrea K. Chomistek, ScD

***Background*—**How physical activity (PA) and sitting time may change after first myocardial infarction (MI) and the association with mortality in postmenopausal women is unknown.

***Methods and Results*—**Participants included postmenopausal women in the Women's Health Initiative-Observational Study, aged 50 to 79 years who experienced a clinical MI during the study. This analysis included 856 women who had adequate data on PA exposure and 533 women for sitting time exposures. Sitting time was self-reported at baseline, year 3, and year 6. Self-reported PA was reported at baseline through year 8. Change in PA and sitting time were calculated as the difference between the cumulative average immediately following MI and the cumulative average immediately preceding MI. The 4 categories of change were: maintained low, decreased, increased, and maintained high. The cut points were ≥7.5 metabolic equivalent of task hours/week versus <7.5 metabolic equivalent of task hours/week for PA and ≥8 h/day versus <8 h/day for sitting time. Cox proportional hazard models estimated hazard ratios and 95% CIs for all-cause, coronary heart disease, and cardiovascular disease mortality. Compared with women who maintained low PA (referent), the risk of all-cause mortality was: 0.54 (0.34–0.86) for increased PA and 0.52 (0.36–0.73) for maintained high PA. Women who had pre-MI levels of sitting time <8 h/day, every 1 h/day increase in sitting time was associated with a 9% increased risk (hazard ratio=1.09, 95% CI: 1.01, 1.19) of all-cause mortality.

***Conclusions*—**Meeting the recommended PA guidelines pre- and post-MI may have a protective role against mortality in postmenopausal women. **(*J Am Heart Assoc*. 2017;6:e005354. DOI: 10.1161/JAHA.116.005354.)**

Key Words: exercise • mortality • myocardial infarction • physical exercise • sitting time • women

Cardiovascular disease (CVD) is responsible for 1 of every 3 deaths in the United States, with coronary heart disease (CHD) causing ≈1 of every 7 deaths.[1] The estimated annual incidence of myocardial infarction (MI) is 660 000 new attacks, with an average age at first MI of 65.1 years for men and 72.0 years for women.[1] Approximately 15% of those who experience an MI will die of it.[1] Smoking cessation, regular physical activity (PA), and dietary changes may reduce mortality by 20% to 35% in MI survivors.[2] Survival after an initial MI is increasing because of the success of secondary prevention programs and promotion of cardiac rehabilitation programs.[3–5] Thus, MI survivors are a growing group and may be motivated to change their behavior to prevent future morbidity and mortality.

From the Division of Internal Medicine, Cardiovascular Research Institute, The University of Kansas Medical Center, Kansas City, KS (A.M.G.); Department of Family Medicine and Epidemiology, Warren Alpert Medical School and School of Public Heath, Brown University, Providence, RI (C.B.E.); Department of Epidemiology and Environmental Health, School of Public Health and Health Professions, University at Buffalo–SUNY, Buffalo, NY (M.J.L.); Brigham and Women's Hospital and Harvard Medical School, Boston, MA (J.E.M.); Departments of Kinesiology (J.D.J.) and Epidemiology and Biostatistics (A.B., K.H., A.K.C.), School of Public Health, Indiana University, Bloomington, IN; Departments of Quantitative Health Sciences and Obstetrics & Gynecology, University of Massachusetts Medical School, Worcester, MA (M.E.W.); Department of Aging and Geriatric Research, University of Florida, Gainesville, FL (T.M.); Division of Cardiology, School of Medicine, George Washington University, Washington, DC (L.W.M.); Department of Medicine, Stanford Prevention Research Center, Stanford University, Stanford, CA (M.L.S.).

Accompanying Tables S1 and S2 are available at http://jaha.ahajournals.org/content/6/5/e005354/DC1/embed/inline-supplementary-material-1.pdf

Correspondence to: Anna M. Gorczyca, PhD, Cardiovascular Research Institute, University of Kansas Medical Center, 3901 Rainbow Blvd, Kansas City, KS 66160. E-mail: agorczyca@kumc.edu

Received February 15, 2017; accepted March 24, 2017.

An estimated 5.8% of global CHD mortality is attributable to physical inactivity after accounting for other CVD risk factors.[6,7] The role of PA, sitting time, and incident CVD risk has been previously assessed in the WHI-OS (Women's Health Initiative-Observational Study) by Manson et al[8] and Chomistek et al.[9] These studies found that higher levels of PA (metabolic equivalent of task hours [MET-h]/week) and lower amounts of prolonged sitting time were associated with a decreased risk of incident coronary events, but their analyses focused on women without past CVD. One previous study investigated change in PA after first MI in a population of 406 men and women from the Corpus Christi Heart Project cohort[10] and found a reduction in all-cause mortality for those who remained active, increased activity, or decreased activity post-MI compared with those who were sedentary pre- and post-MI. However, this study was relatively small and did not examine sitting time, which may be a distinct construct from lack of PA.[11]

While there is substantial evidence that physical activity lowers risk of incident CVD, less is known on the benefits of PA for decreasing mortality post-MI. Additionally, more research is needed on the potential effect of changing other lifestyle habits, such as sitting time, following an MI. Therefore, the purpose of the current study was to examine change in PA and sitting time among survivors of a first MI on all-cause, CHD, and CVD mortality in the WHI-OS.

Methods

Women's Health Initiative

The goal of the WHI was to investigate major causes of morbidity and mortality in a nationally representative cohort of postmenopausal women. The WHI-OS cohort included 93 676 postmenopausal women, aged 50 to 79 years at study entry, from 40 US clinical centers and enrolled between 1993 and 1998.[12] Details on the reliability and measurement of baseline characteristics in the WHI have been previously published.[13] All study sites obtained informed consent and institutional review board approval.

We identified 3129 women who experienced a first MI during follow-up out of the original 93 676 women in the WHI-OS. Nonfatal MI was confirmed based on standard diagnostic criteria for electrocardiography changes, elevated cardiac enzymes, or both.[14] We then excluded 979 women with baseline prevalent CHD, stroke, or cancer, 61 women missing information on sitting or PA at baseline, and 89 women who reported they were unable to walk one block at baseline. Furthermore, 1144 women were excluded from the PA analysis because of MI occurring after the last measurement of PA and 1467 women were excluded from the sitting time analysis because of MI occurring after the last measurement of sitting time. Thus, 856 women were included in the PA analysis and 533 in the sitting-time analysis.

Exposure Assessment

Baseline characteristics were self-reported on questionnaires, including demographics, medical history, diet, smoking, and other lifestyle factors. Participants completed follow-up assessments periodically after enrollment. The study protocol was approved by the institutional review board of each site, and all women provided written informed consent.

Recreational PA was self-reported at baseline and annually through year 8 by detailed questionnaire. Information on walking frequency, duration, and pace, specifically outside of the home, was asked as well as information on other types of activity (mild, moderate, and strenuous). Examples of mild activity included slow dancing, bowling, and golf. Examples of moderate activity were biking outdoors, using an exercise machine, calisthenics, easy swimming, and popular or folk dancing. Examples of strenuous activity were aerobics, aerobic dancing, jogging, tennis, and swimming laps. Each type of activity was assigned an MET score on the basis of energy cost,[15] and PA-related energy expenditure (MET-h/week) was calculated as the summed product of the frequency, duration, and intensity of the activity. A random sample of 536 participants had second measurements conducted on all PA $\approx$10 weeks after baseline. Test-retest reliability for the PA variables was 0.53 to 0.72 with the intraclass correlation 0.77 for total PA.[16]

Sitting time was assessed by questionnaire at baseline and twice during follow-up (year 3 and year 6) with the following question: "During a usual day and night, about how many hours do you spend sitting? Be sure to include the time you spend sitting at work, sitting at the table eating, driving or riding in a car or bus, and sitting up watching TV or talking." Eight categories were provided for the response, ranging from less than 4 hours to 16 or more hours.

To represent long-term exposure,[17] the cumulative average for PA, sitting time, and walking was calculated from questionnaires at baseline, year 3 to year 8 for PA and walking and baseline, year 3, and year 6 for sitting time. Change in PA, walking, and sitting time were calculated as the difference between the cumulative average immediately following MI and the cumulative average immediately preceding MI. Thus, pre-MI PA is the average of all measurements before the MI, and post-MI PA is the average of all measurements after the MI. For physical activity, we used 7.5 MET-h/week as the cut point, which is equivalent to accumulating 150 min/week of moderate-intensity exercise, consistent with the current PA guidelines.[18] Walking categories were determined based on the median of the data, with 3.5 MET-h/week being equivalent to 1 h/day of brisk

walking. Sitting-time categories were determined based on previous research in the aging population[19] using 8 h/day as the cut point. The 4 categories of change were: maintained low, decreased, increased, and maintained high. The cut points were as follows: PA, ≥7.5 MET-h/week (high) versus <7.5 MET-h/week (low); walking, ≥3.5 MET-h/week (high) versus <3.5 MET-h/week (low); and sitting time, ≥8 h/day (high) versus <8 h/day (low).

Ascertainment of End Points

The primary end points for this analysis were all-cause, CHD, and CVD mortality. Underlying cause of death was identified through medical records, death certificates, and autopsy reports.[14] Physicians blinded to the exposure information adjudicated the event. CHD and CVD mortality were confirmed through documentation on hospital or autopsy records of coronary disease or CVD was listed as the cause of death on death certificates.

Statistical Analysis

All analyses were performed using SAS statistical software (version 9.4; SAS Institute Inc, Cary, NC). Eligible participants contributed person-time from return of the questionnaire immediately following first clinical MI to death from any cause, loss to follow-up, or August 29, 2014, whichever occurred first. Baseline characteristics were compared according to categories of change in PA with a chi-squared test for categorical variables and generalized linear model for continuous variables. We examined the association between pre- and post-MI levels of PA, walking and sitting time, and risk of all-cause, CHD, and CVD mortality using Cox proportional hazards models to estimate hazard ratios (HRs) and 95% CIs. The categories were: >20, 7.5 to 20, 1.8 to 7.4, and ≤1.7 MET-h/week for physical activity; ≥3.5 and <3.5 MET-h/week for walking; and ≤5, 5.1 to 7.9, and ≥8 h/day for sitting time.

We also examined the association between categories of change in PA, walking, and sitting time with risk of all-cause, CHD, and CVD mortality using the 4 categories of change described above: maintained low, decreased, increased, and maintained high. Additionally, to further explore the association between change in PA, walking, and sitting time with all-cause mortality, we assessed change in each exposure continuously, stratified by pre-MI levels. Finally, conditional relative PA was calculated to express the relative PA change from pre-MI to post-MI, which was uncorrelated with PA pre-MI, to estimate the independent contribution of PA change on mortality.[20] Conditional relative PA was calculated as residuals by regressing post-MI PA on pre-MI PA.

Three models were used to evaluate the association between change in PA and sitting time after an MI and mortality. The first model was stratified by age only. The second model additionally included race, education, income, marital status, heart failure, cigarette smoking, family history of MI, alcohol consumption, Healthy Eating Index diet score, hours of sleep, depression, sitting time (for PA model), PA (for sitting time model), and vigorous PA (for walking model). The final model also adjusted for diabetes mellitus, hypertension, hyperlipidemia, body mass index, coronary artery bypass graft, and percutaneous transluminal coronary angioplasty. To account for potential bias attributed to severity of MI, in addition to adjusting for heart failure, we conducted a sensitivity analysis by excluding women who died within 2 years of MI and compared with the original analysis.

Results

Baseline characteristics according to category of change in PA are presented in Table 1. Women who maintained high PA pre-MI and post-MI were more likely to have attended college, be married, have a lower body mass index, and have an overall healthier diet at baseline compared with women who maintained low PA pre- and post-MI.

During a median follow-up of 7.2 years, 265 of the 856 women included in the PA analysis and 225 of the 533 women included in the sitting-time analysis died. In multivariable-adjusted analyses, PA pre- and post-MI was inversely associated with all-cause and CVD mortality (Table 2). Compared with women who reported >20 MET-h/week of PA pre-MI, women with ≤1.7 MET-h/week pre-MI had an HR of 1.61 (95% CI, 1.00, 2.60; *P* for trend, <0.01) for all-cause mortality and 3.29 (95% CI, 2.03–5.33) for post-MI PA ≤1.7 MET-h/week. Similarly, for CVD mortality, women with ≤1.7 MET-h/week pre-MI had a HR of 2.00 (95% CI, 0.92, 4.34; *P* for trend=0.02) and 3.69 (95% CI, 1.61–8.47; *P* for trend, 0.001) for post-MI PA compared with women reporting >20 MET-h/week. Walking <3.5 MET-h/week compared with ≥3.5 MET-h/week pre-MI was associated with an increased risk of all-cause mortality (HR=1.44; 95% CI, 1.02–2.03; *P* for trend=0.04).

Means and SDs of PA pre- and post-MI by categories of change in PA are presented in Table S1. The average weekly PA for those who decreased PA was 15.33±7.87 MET-h/week pre-MI and 3.01±2.44 MET-h/week post-MI. For those who increased PA, average weekly PA was 3.47±2.34 MET-h/week pre-MI and 14.47±7.32 MET-h/week post-MI. Age and multivariable-adjusted HRs for all-cause, CHD, and CVD mortality by categories of change in PA, sitting time, and walking are presented in Table 3. Using maintained low PA as the reference group, the HRs for all-cause mortality for women who increased PA and maintained high PA were 0.54 (95% CI, 0.34–0.82) and 0.52 (95% CI, 0.36–0.73), respectively. Again, using maintained low PA as the reference group,

Table 1. Baseline Characteristics According to Change in PA Among Postmenopausal Women Who Survived an MI: WHI-OS

Change in Physical Activity Levels					
	Maintained Low PA	Decreased PA	Increased PA	Maintained High PA	*P* Value
No. of participants	296	123	111	326	
Age, y	67.9 (6.8)	67.9 (7.0)	64.8 (6.8)	67.3 (6.6)	0.07
PA, MET-h/week	3.4 (4.5)	17.9 (11.1)	3.8 (3.7)	20.9 (14.8)	<0.001
Sitting time, h/day	7.7 (3.3)	7.1 (3.3)	7.7 (3.1)	7.0 (3.1)	0.02
Race, %					0.81
White	89	90	91	91	
Black	8	1	1	2	
Hispanic/Latino	1	2	1	2	
Other	2	2	2	2	
Smoking status, %					0.02
Never	45	45	41	48	
Past	43	47	47	47	
Current	12	8	13	4	
Age at menopause, y	47.8 (6.6)	46.5 (7.0)	46.9 (7.1)	48.2 (6.9)	<0.40
Alcohol, drinks/week	1.4 (3.1)	1.8 (3.2)	2.1 (3.8)	2.5 (5.0)	<0.001
Education, %					<0.001
High School	35	25	35	17	
Vocational	11	12	15	11	
College	53	62	50	71	
Income, %					<0.001
<20 000	25	31	17	11	
20 000 to 74 999	61	54	65	65	
>75 000	6	5	10	16	
Marital status, %					<0.01
Yes	53	46	66	60	
No	48	54	34	40	
HRT use ever, %	50	48	59	61	<0.01
Waist-to-hip ratio	0.83 (0.08)	0.83 (0.09)	0.83 (0.07)	0.81 (0.07)	<0.001
Body mass index	29.5 (7.0)	28.1 (6.5)	29.1 (6.1)	26.4 (4.3)	<0.001
Depression, %	12	13	9	8	0.09
Family history of MI, %	50	53	58	54	0.57
CABG, %	7	4	3	5	0.31
PTCA, %	6	7	1	4	0.09
Hx of diabetes mellitus, %	19	13	12	9	<0.01
Hx hypertension, %	58	50	51	47	0.05
Hx hyperlipidemia, %	25	26	20	25	0.75
HEI diet quality	65.8 (11.5)	69.5 (10.1)	67.5 (11.7)	71.9 (9.9)	<0.001
Sleep, h/day	8.0 (2.4)	8.2 (2.8)	8.2 (2.1)	8.2 (2.3)	0.28
Heart failure*, %	13	13	10	10	0.57

CABG indicates coronary artery bypass grafting; HEI, Healthy Eating Index; HRT, hormone replacement therapy; Hx, history; MET-h, metabolic equivalent of task hours; MI, myocardial infarction; PA, physical activity; PTCA, percutaneous transluminal coronary angioplasty; WHI-OS, Women's Health Initiative-Observational Study.
*Heart failure that occurred during follow-up.

Table 2. HRs and 95% CIs for All-Cause, CHD, and CVD Mortality in Relation to Categories of Pre- and Post-MI PA, Sitting Time, and Walking*

	PA (MET-h/week)					Sitting Time (h/day)					Walking (MET-h/week)	
	>20	7.5 to 20	1.8 to 7.4	≤1.7	P_{trend}	≤5	>5 to <8	≥8	P_{trend}	≥3.5	<3.5	P_{trend}
All-cause mortality												
Person-years	2062	3895	3321	1838		1761	2862	2358		4063	6150	
No. of deaths	39	82	93	61		36	74	56		78	172	
Pre-MI, HR	1.00	1.31	1.78	1.46	0.02	1.00	0.93	0.90	0.75	1.00	1.44	0.04
95% CI		0.86 to 2.00	1.15 to 2.74	0.91 to 2.35			0.58 to 1.49	0.53 to 1.53			1.02 to 2.03	
Person-years	1937	4114	2855	2210		2774	1652	2555		3382	6830	
No. of deaths	32	72	72	99		58	33	75		64	186	
Post-MI, HR	1.00	1.16	1.55	3.29	<0.001	1.00	1.10	1.29	0.26	1.00	1.37	0.09
95% CI		0.73 to 1.84	0.96 to 2.49	2.03 to 5.33			0.66 to 1.82	0.83 to 1.99			0.95 to 1.98	
CHD mortality												
No. of deaths	10	17	27	10		7	21	13		16	42	
Pre-MI, HR	1.00	0.75	2.07	1.10	0.27	1.00	0.72	0.74	0.76	1.00	2.03	0.12
95% CI		0.29 to 1.95	0.82 to 5.24	0.36 to 3.41			0.18 to 2.97	0.17 to 3.22			0.84 to 4.90	
No. of deaths	5	17	18	24		16	9	16		10	48	
Post-MI, HR	1.00	2.54	5.44	8.80	<0.001	1.00	2.15	1.59	0.58	1.00	2.42	0.08
95% CI		0.64 to 10.09	1.37 to 21.68	2.12 to 36.68			0.62 to 7.52	0.46 to 5.50			0.91 to 6.43	
CVD mortality												
No. of deaths	15	32	46	27		17	36	22		33	75	
Pre-MI, HR	1.00	1.17	2.04	1.74	0.04	1.00	0.68	0.77	0.62	1.00	1.39	0.22
95% CI		0.59 to 2.33	1.05 to 3.98	0.82 to 6.69			0.33 to 1.42	0.33 to 1.76			0.82 to 2.34	
No. of deaths	11	33	32	44		26	17	32		22	86	
Post-MI, HR	1.00	1.61	2.40	3.69	0.001	1.00	1.27	1.49	0.31	1.00	1.79	0.05
95% CI		0.72 to 3.56	1.07 to 5.39	1.61 to 8.47			0.60 to 2.71	0.71 to 3.10			1.00 to 3.22	

CHD indicates coronary heart disease; CVD, cardiovascular disease; HR, hazard ratio; MET-h, metabolic equivalent of task hours; MI, myocardial infarction; PA, physical activity.
*Adjusted for age (stratified), education, race, income (updated), marital status (updated), hormone replacement therapy use, physical function, congestive heart failure (updated), depression, family history MI, cigarette smoking (updated), sleep, alcohol drinks per week, age at menopause, Healthy Eating Index 2005, PA (sitting time), sitting time (PA), vigorous PA (walking), high cholesterol requiring pills, coronary artery bypass grafting, percutaneous transluminal coronary angioplasty, hypertension, diabetes mellitus, and body mass index.

DOI: 10.1161/JAHA.116.005354

Table 3. All-Cause, CHD, and CVD Mortality by Change in PA, Sitting Time, and Walking After First MI: WHI-OS

	Deaths	Unadjusted Rates, Per 1000 Person-Years	Age-Adjusted	Multivariable-Adjusted*	Fully Adjusted†
PA					
All-cause mortality					
Maintained low PA‡	125	415	1.00	1.00	1.00
Decreased PA§	44	271	0.89 (0.62–1.29)	0.96 (0.65–1.44)	0.99 (0.66–1.48)
Increased PA‖	27	233	0.45 (0.29–0.69)	0.52 (0.33–0.82)	0.54 (0.34–0.86)
Maintained high PA¶	79	265	0.41 (0.31–0.55)	0.51 (0.36–0.72)	0.52 (0.36–0.73)
CHD mortality					
Maintained low PA	31	111	1.00	1.00	1.00
Decreased PA	11	76	0.90 (0.42–1.92)	0.65 (0.27–1.58)	0.84 (0.34–2.10)
Increased PA	6	33	0.46 (0.19–1.12)	0.41 (0.15–1.12)	0.39 (0.13–1.15)
Maintained high PA	16	57	0.31 (0.16–0.60)	0.29 (0.13–0.64)	0.26 (0.11–0.60)
CVD mortality					
Maintained low PA	58	203	1.00	1.00	1.00
Decreased PA	18	102	0.78 (0.44–1.37)	0.81 (0.43–1.52)	0.82 (0.44–1.55)
Increased PA	14	92	0.55 (0.30–1.00)	0.61 (0.32–1.16)	0.59 (0.30–1.15)
Maintained high PA	30	109	0.34 (0.21–0.54)	0.43 (0.25–0.74)	0.41 (0.24–0.71)
Sitting time					
All-cause mortality					
Maintained high sitting#	46	350	1.00	1.00	1.00
Increased sitting**	29	427	1.32 (0.80–2.18)	1.52 (0.87–2.66)	1.46 (0.81–2.65)
Decreased sitting††	32	316	0.89 (0.56–1.42)	1.02 (0.60–1.74)	1.13 (0.65–1.99)
Maintained low sitting‡‡	58	258	0.67 (0.44–1.02)	0.84 (0.52–1.36)	0.86 (0.51–1.45)
CHD mortality					
Maintained high sitting	11	81	1.00	1.00	1.00
Increased sitting	5	101	0.80 (0.25–2.58)	1.46 (0.35–6.05)	2.37 (0.41–13.75)
Decreased sitting	11	63	1.26 (0.53–2.99)	1.52 (0.50–4.59)	1.47 (0.32–6.73)
Maintained low sitting	13	76	0.45 (0.19–1.06)	6.65 (0.20–2.11)	0.60 (0.18–2.81)
CVD mortality					
Maintained high sitting	20	138	1.00	1.00	1.00
Increased sitting	12	202	1.25 (0.58–2.70)	1.37 (0.56–3.38)	1.55 (0.58–4.11)
Decreased sitting	15	139	0.95 (0.47–1.89)	1.10 (0.49–2.46)	1.05 (0.43–2.57)
Maintained low sitting	27	129	0.62 (0.33–1.15)	0.75 (0.35–1.57)	0.70 (0.30–1.64)
Walking					
All-cause mortality					
Maintained low walking§§	166	377	1.00	1.00	1.00
Decreased walking‖‖	14	143	0.66 (0.43–1.02)	0.69 (0.44–1.10)	0.70 (0.42–1.07)
Increased walking¶¶	24	242	0.59 (0.34–1.04)	0.62 (0.34–1.14)	0.68 (0.37–1.27)
Maintained high walking##	47	247	0.60 (0.42–0.87)	0.67 (0.45–1.01)	0.65 (0.42–0.99)
CHD mortality					
Maintained low walking	45	102	1.00	1.00	1.00
Decreased walking	1	10	0.85 (0.39–1.89)	0.58 (0.23–1.45)	0.60 (0.21–1.70)

Continued

Table 3. Continued

	Deaths	Unadjusted Rates, Per 1000 Person-Years	Age-Adjusted	Multivariable-Adjusted*	Fully Adjusted†
Increased walking	4	40	0.29 (0.07–1.22)	0.32 (0.06–1.63)	0.44 (0.08–2.37)
Maintained high walking	9	47	0.32 (0.12–0.82)	0.36 (0.11–1.00)	0.34 (0.10–1.14)
CVD mortality					
Maintained low walking	79	180	1.00	1.00	1.00
Decreased walking	5	51	0.80 (0.44–1.47)	0.78 (0.41–1.50)	0.77 (0.39–1.51)
Increased walking	8	80	0.35 (0.12–0.97)	0.36 (0.12–1.08)	0.39 (0.12–1.22)
Maintained high walking	17	89	0.52 (0.29–0.93)	0.62 (0.33–1.19)	0.57 (0.29–1.12)

CHD indicates coronary heart disease; CVD, cardiovascular disease; MI, myocardial infarction; PA, physical activity WHI-OS, Women's Health Initiative-Observational Study.
*Adjusted for age, education, race, income (updated), marital status (updated), hormone replacement therapy use, physical function, congestive heart failure (updated), depression, family history MI, cigarette smoking (updated), sleep, alcohol drinks per week, age at menopause, Healthy Eating Index 2005, PA (sitting time), sitting time (PA), and vigorous PA (walking).
†Multivariable-adjusted model+high cholesterol requiring pills, coronary artery bypass grafting, percutaneous transluminal coronary angioplasty, hypertension, diabetes mellitus, and body mass index.
‡<7.5 (metabolic equivalent of task hours/week), no change.
§≥7.5 to <7.5 (metabolic equivalent of task hours/week).
‖<7.5 to ≥7.5 (metabolic equivalent of task hours/week).
¶≥7.5 (metabolic equivalent of task hours/week), no change.
#≥8 (h/day), no change.
**<8 to ≥8 (h/day).
††≥8 to <8 (h/day).
‡‡<8 (h/day), no change.
§§<3.5 (metabolic equivalent of task hours/week), no change.
‖‖≥3.5 to <3.5 (metabolic equivalent of task hours/week).
¶¶<3.5 to ≥3.5 (metabolic equivalent of task hours/week).
##≥3.5 (metabolic equivalent of task hours/week), no change.

the HRs for CHD and CVD mortality for women who maintained high PA were 0.26 (95% CI, 0.11–0.60) and 0.41 (95% CI, 0.24–0.71), respectively. When we investigated walking specifically, the all-cause mortality HR for women who maintained high walking was 0.65 (95% CI, 0.42–0.99), compared with women who maintained low walking pre- and post-MI. Change in sitting time as a categorical variable was not significantly associated with all-cause, CHD, or CVD mortality.

We then examined continuous change in PA, sitting time, and walking, stratified by pre-MI levels (Table 4). Among women who reported PA <7.5 MET-h/week pre-MI, there was an 8% decreased risk (HR=0.92; 95% CI, 0.88, 0.96) of all-cause mortality, 16% decreased risk of CHD mortality (HR=0.84; 95% CI, 0.76, 0.93), and 9% decreased risk of CVD mortality (HR=0.91; 95% CI, 0.86, 0.96) for a 1 MET-h/week increase in PA. Among those women reporting PA ≥7.5 MET-h/week pre-MI, there was an 8% decreased risk of CHD mortality for a 1 MET-h/week increase in PA. HRs for continuous change in PA were not statistically significant among women who reported PA levels that met the PA guidelines pre-MI for all-cause and CVD mortality. Women who had pre-MI levels of sitting time <8 h/day had a 9% higher risk (HR=1.09; 95% CI: 1.01, 1.19) of all-cause mortality for every 1 h/day increase in sitting time. The HR for continuous change in sitting time was not statistically significant among women who reported sitting time >8 h/day pre-MI. Finally, results for walking were similar to that for PA, but stronger. Women who had pre-MI levels of walking <3.5 MET-h/week had a 19% decreased risk of all-cause mortality (HR=0.81; 95% CI, 0.72, 0.91), 35% decreased risk of CHD mortality (HR=0.65; 95% CI, 0.45–0.94), and 34% decreased risk of CVD mortality (HR=0.66; 95% CI, 0.52–0.83) for a 1 MET-h/week increase in walking.

Similar results were found when conditional relative PA was assessed in relation to all-cause, CHD, and CVD mortality in both age- and multivariate-adjusted models (Table S2). After excluding women who died within the first 2 years post-MI, the results were similar.

Discussion

In this prospective study of postmenopausal MI survivors in the United States, maintaining at least 7.5 MET-h/week of PA pre- to post-MI was associated with lower risk of all-cause, CHD, and CVD mortality. Additionally, individuals who increased PA after a first MI had a lower risk of all-cause mortality compared with women who maintained low PA. Finally, when examined continuously, increased sitting time post-MI was associated with an increased risk of all-cause mortality among individuals with low sitting time (<8 h/day) pre-MI.

Table 4. All-Cause, CHD, and CVD Mortality in Relation to Continuous Change in PA, Sitting Time, and Walking Following MI, Stratified by Pre-MI Levels of PA, Sitting Time, and Walking

	Age-Adjusted	Multivariable-Adjusted*
Pre-MI PA	HR (95% CI) for a 1 MET-h/week increase in PA	
All-cause mortality		
≥7.5 MET-h/week	0.98 (0.97–1.00)	0.99 (0.97–1.01)
<7.5 MET-h/week	0.92 (0.89–0.96)	0.92 (0.88–0.96)
CHD mortality		
≥7.5 MET-h/week	0.94 (0.90–0.97)	0.92 (0.87–0.98)
<7.5 MET-h/week	0.88 (0.81–0.96)	0.84 (0.76–0.93)
CVD mortality		
≥7.5 MET-h/week	0.98 (0.95–1.00)	0.98 (0.95–1.01)
<7.5 MET-h/week	0.91 (0.87–0.96)	0.91 (0.86–0.96)
Pre-MI sitting time	HR (95% CI) for a 1 h/day increase in sitting time	
All-cause mortality		
≥8 h/day	1.11 (0.99–1.24)	1.14 (0.97–1.35)
<8 h/day	1.11 (1.04–1.19)	1.09 (1.01–1.19)
CHD mortality		
≥8 h/day	1.08 (0.89–1.33)	1.16 (0.79–1.69)†
<8 h/day	1.01 (0.86–1.19)	1.05 (0.87–1.28)†
CVD mortality		
≥8 h/day	1.08 (0.92–1.28)	1.05 (0.62–1.79)‡
<8 h/day	1.13 (0.99–1.22)	1.07 (0.94–1.21)
Pre-MI walking	HR (95% CI) for a 1 MET-h/week increase in walking	
All-cause mortality		
≥3.5 MET-h/week	1.02 (0.96–1.08)	1.03 (0.95–1.11)
<3.5 MET-h/week	0.85 (0.77–0.94)	0.81 (0.72–0.91)
CHD mortality		
≥3.5 MET-h/week	1.05 (0.94–1.18)	1.17 (0.85–1.60)‡
<3.5 MET-h/week	0.68 (0.53–0.88)	0.65 (0.45–0.94)
CVD mortality		
≥3.5 MET-h/week	1.06 (0.97–1.16)	1.05 (0.93–1.23)
<3.5 MET-h/week	0.73 (0.61–0.87)	0.66 (0.52–0.83)

CHD indicates coronary heart disease; CVD, cardiovascular disease; HR, hazard ratio; MET-h, metabolic equivalent of task hours; MI, myocardial infarction; PA, physical activity.
*Adjusted for age, education, race, income (updated), marital status (updated), hormone replacement therapy use, physical function, congestive heart failure (updated), depression, family history MI, cigarette smoking (updated), sleep, alcohol drinks per week, age at menopause, Healthy Eating Index 2005, PA (sitting time), sitting time (PA), and vigorous PA (walking).
†Because of model convergence criterion, we used a reduced model: adjusted for age, education, race, physical function, congestive heart failure (updated), cigarette smoking (updated), and PA (sitting time).
‡Because ofmodel convergence criterion, we used a reduced model: adjusted for age, education, race, income (updated), marital status (updated), hormone replacement therapy use, physical function, congestive heart failure (updated), depression, family history MI, cigarette smoking (updated), age at menopause, Healthy Eating Index 2005, and vigorous PA (walking).

Only 1 study to date has examined the association between change in PA after a first MI.[10] Thus, the current analysis, which assesses the association between change in PA, sitting time, and walking and all-cause, CHD, and CVD mortality provides a significant contribution to the current literature. Our results are consistent with a recent study that found[10] lower risk of all-cause mortality in individuals who maintained high PA, or increased PA after a first MI compared with those who maintained low PA pre- and post-MI. Although the earlier study included both men and women, the number of women was small (150) and the instrument used to measure PA was not validated. Moreover, sitting time was not considered a separate construct from physical inactivity in the analysis and walking was not examined in addition to total PA. We extend this research by examining the association of change in sitting time and PA with mortality as independent entities in postmenopausal women. Additionally, by using the cumulative average of PA, sitting time, and walking pre- and post-MI, we were able to capture long-term exposure.[17] Because of the timing and frequency of the exposure measurements throughout the study, using cumulative average is more representative of long-term exposure for PA and walking, but not necessarily for sitting time, because it was only assessed 3 times throughout follow-up.

When examined categorically, change in sitting time was not associated with mortality in the main analysis. However, when examined continuously, we did observe an increased risk of all-cause mortality for every 1-h/day increase in sitting time in those women who sat for 8 or less hours/day pre-MI. Our study is the first population-based study to investigate change in sitting time after a first MI.

Several mechanisms may explain why our results were stronger for CVD mortality compared to all-cause mortality. Prolonged sitting has been associated with increased total cholesterol, triglycerides, waist circumference, decreased glucose uptake, and decreased skeletal muscle lipoprotein lipase activity.[21–23] Previous research has shown that repeated bouts of prolonged sitting result in low shear rates leading to endothelial dysfunction, which has also been linked to vascular mortality.[24] Breaking up sitting time with light PA has been shown to counteract the adverse effects on the endothelium.[24] Last, increased lifestyle PA, including walking, post-MI has been associated with improvement in cardiorespiratory fitness,[25] which has been shown to have prognostic benefit even in patients with reduced left ventricular ejection fraction.[26]

A potential source of bias could be that individuals did not increase their PA or decrease their sitting time because of the severity of their first MI. Unfortunately, we did not have information on MI severity; however, we did exclude women unable to walk at least 1 block and controlled for congestive heart failure, which was updated throughout the study within our multivariate models in an attempt to adjust for severity.

We also conducted a sensitivity analysis excluding women who died within 2 years of their MI, and results were similar to our main analysis. When excluding 47 women who died within 2 years of their MI, the HRs in the fully adjusted model for all-cause mortality in women who maintained high PA was 0.55 (95% CI, 0.37–0.81), compared with women who maintained low PA. Additionally, the women excluded from the analysis for missing or inadequate data did not differ from those included in the analysis on baseline PA, baseline sitting time, age, smoking status, body mass index, or Healthy Eating Index diet quality.

Our study had several strengths, including its prospective design, the large multiethnic cohort of postmenopausal women, wide variety of information on covariates, and detailed longitudinal information on PA and sitting time. This is the first study to investigate the association of change in sitting time and walking after a first MI and subsequent mortality.

The limitations of the present study include some aspects of exposure assessment. First, sitting time was measured only at baseline, year 3, and year 6. More-frequent ascertainment of sitting time would have provided estimates of sitting times more proximal to time of MI; we were unable to examine changes in sitting time that occurred more frequently than our measurement timing. Additionally, both PA and sitting time were self-reported. Nonetheless, the PA measurement has been validated in this cohort,[27] and measurement error is likely to be nondifferential because of the prospective nature of the study. Accelerometers could provide more-accurate measurements of sitting time and PA.[28] The results of this study are applicable only to postmenopausal women and may not be generalizable to younger women, populations with a different distribution of race/ethnicity, or men. Additionally, there are a small number of deaths in some of the categories. Finally, as with any observational study, residual confounding by other lifestyle factors should be taken into consideration.

With the improvement in medical care, there are increasing numbers of MI survivors,[9] a group of individuals who may be highly motivated to make lifestyle changes. Thus, the present study has important public health implications, particularly given the high prevalence of prolonged sitting time and PA in the population. The results of the current study suggest that women who survive an initial MI should limit sedentary time and increase PA, such as walking, to decrease subsequent mortality. However, we encourage women with a history of MI to consult with their physician before increasing PA to ensure that it is safe for them to do so.

Appendix

Abbreviated List of WHI Investigators: Program Office: (National Heart, Lung, and Blood Institute, Bethesda, Maryland) Jacques Rossouw, Shari Ludlam, Dale Burwen, Joan McGowan, Leslie Ford, and Nancy Geller.

Clinical Coordinating Center: Clinical Coordinating Center: (Fred Hutchinson Cancer Research Center, Seattle, WA) Garnet Anderson, Ross Prentice, Andrea LaCroix, and Charles Kooperberg.

Investigators and Academic Centers: (Brigham and Women's Hospital, Harvard Medical School, Boston, MA) JoAnn E. Manson; (MedStar Health Research Institute/Howard University, Washington, DC) Barbara V. Howard; (Stanford Prevention Research Center, Stanford, CA) Marcia L. Stefanick; (The Ohio State University, Columbus, OH) Rebecca Jackson; (University of Arizona, Tucson/Phoenix, AZ) Cynthia A. Thomson; (University at Buffalo, Buffalo, NY) Jean Wactawski-Wende; (University of Florida, Gainesville/Jacksonville, FL) Marian Limacher; (University of Iowa, Iowa City/Davenport, IA) Robert Wallace; (University of Pittsburgh, Pittsburgh, PA) Lewis Kuller; (Wake Forest University School of Medicine, Winston-Salem, NC) Sally Shumaker.

Sources of Funding

The WHI program is funded by the National Heart, Lung, and Blood Institute, National Institutes of Health, US Department of Health and Human Services through contracts, HHSN268201100046C, HHSN268201100001C, HHSN268201100002C, HHSN268201100003C, and HHSN268201100004C.

Disclosures

None.

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SUPPLEMENTAL MATERIAL

Table S1. Means and standard deviations of physical activity (PA) pre- and post-myocardial infarction (MI) in MET-hrs/wk by categories of change in PA.

	N	Mean	Std. Dev.
Maintained low PA			
Pre-MI PA	296	2.62	2.23
Post-MI PA	296	2.02	2.19
Decreased PA			
Pre-MI PA	123	15.33	7.87
Post- MIPA	123	3.01	2.44
Increased PA			
Pre-MI PA	111	3.47	2.34
Post- MI PA	111	14.47	7.32
Maintained high PA			
Pre-MI PA	326	20.65	12.00
Post-MI PA	326	19.74	11.25

Table S2. Hazard ratios (HR) and 95% confidence intervals (CI) for all-cause, coronary heart disease (CHD), and cardiovascular disease (CVD) mortality in relation to conditional relative physical activity.

	Age-adjusted	Multivariable-adjusted*
Conditional Relative PA	**HR (95% CI) for a 1 MET-hr/week Increase in Physical Activity**	
All-Cause Mortality	0.96 (0.95-0.98)	0.97 (0.95-0.99)
CHD Mortality	0.92 (0.89-0.96)	0.93 (0.90-0.97)
CVD Mortality	0.96 (0.93-0.98)	0.97 (0.95-0.99)

* Adjusted for age (stratified), education, race, income (updated), marital status (updated), hormone replacement therapy use, physical function, congestive heart failure (updated), depression, family history MI, cigarette smoking (updated), sleep, alcohol drinks per week, age a menopause, Healthy Eating Index 2005, and sitting time

Change in Physical Activity and Sitting Time After Myocardial Infarction and Mortality Among Postmenopausal Women in the Women's Health Initiative–Observational Study

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J Am Heart Assoc. 2017;6:e005354; originally published May 15, 2017;
doi: 10.1161/JAHA.116.005354
The *Journal of the American Heart Association* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Online ISSN: 2047-9980