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Research Article

Occupational Physical Activity and Coronary Heart Disease in Women's Health Initiative Observational Study

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Abstract

Background: Women comprise nearly half of the labor force in our society, but the impact of the occupational psychical activity on women's heart health in later life was unclear. We conducted a case-cohort study to assess the association of occupational physical activity (OPA), alone and jointly with leisure-time physical activity (LTPA) and risk of coronary heart disease (CHD).

Methods: We included women enrolled in Women's Health Initiative Observational Study who provided an occupational history at baseline and were followed until 2013 for the first occurrence of myocardial infarction or death from CHD (mean age ± *SD* = 63.4 ± 7.2). A total of 5,243 women free of CHD at baseline were randomly selected into a subcohort and 3,421 CHD events were adjudicated during follow-up. Through linkage of Standard Occupational Classification codes to the Occupational Information Network, we assessed cumulative and most recent exposure of OPA. LTPA was assessed through Women's Health Initiative's physical activity questionnaire. Weighted Cox proportional hazard models were used to evaluate CHD risk.

Results: After adjustment for demographic and socioeconomic factors, levels of OPA were not associated with CHD risk. Compared with women with low OPA and high LTPA, women with moderate to high cumulative OPA and low LTPA had relative high CHD risk (hazard ratio [HR]: 1.54, 95% confidence interval [CI]: 1.26, 1.88 for moderate OPA and HR: 1.46. 95% CI: 1.20, 1.78 for high OPA).

Discussion: Results from this study suggest no overall association between lifetime OPA and CHD risk in women, but the impact of OPA varies by LTPA levels.

Keywords: Lifetime, Occupations, Leisure time, Cardiovascular disease

Physical activity is measured in four domains: occupational, transportation, household, and leisure-time activities (1). Occupational research has focused on physical demands (eg, repetitive motion and heavy lifting) in relation to musculoskeletal disorders (2); however, with rise of obesity rate, health impacts of sedentary work have attracted attention (3). Evidence indicates that occupational physical activity (OPA) is negatively correlated with leisure-time physical activity (LTPA) (4) and that the effect of OPA may depend on LTPA (5). Ignoring the complex relationship between OPA and LTPA may obscure the true effects of OPA on coronary heart disease (CHD) (6,7).

Although the level of overall physical activity decreases with aging (8), physical activity provides greater protection against CHD to older rather than younger people (9). However, most prior studies did not distinguish occupational and non-occupational physical activity, and the potential effect of OPA on CHD in older people is still unclear (10). Moreover, existing studies measured OPA based on a single time-point (11). Level of OPA may vary across the life span (11), and a single measurement does not evaluate the effect of long-term OPA on CHD risk in later life.

Compared with men, women have the higher CHD mortality rate after age 45 (12) and are more likely to be continuously employed in physically demanding occupations at high age (13), suggesting that the influence of OPA on CHD may differ by sex. The effect of OPA on CHD estimated from studies that primarily included men cannot be to women. Several recent studies have explored the association between OPA and CHD in women but the results were inconsistent, with both null (14–16) and positive associations (17,18) reported. Therefore, the potential impact of OPA on CHD in women's later life is not known.

To address these gaps in these studies, we evaluated the association between OPA, LTPA, and the CHD risk among women, using data from the Women's Health Initiative–Observational Study (WHI-OS).

Methods

The WHI-OS consists of 93,676 postmenopausal women (50–79 years of age), enrolled from 1993 to 1998 at 40 clinical centers in the United States. Participants were followed until 2005 and among these who consented to participate in the WHI Extension Study were followed for an additional 8 years from 2005 to 2013. Participants responded to annual questionnaires to ascertain health outcomes (eg, CHD), followed by medical adjudication. Approximately 94% of participants responded to the questionnaires every year over an average of 11.4 years of follow-up (19). A total of 91,627 participants who answered the self-reported occupational history questionnaires were eligible for inclusion in this study. Detailed information on the recruitment of WHI participants was presented elsewhere (19).

Study Design and Population

We used a case-cohort design because the objective measure of OPA was not available for the entire cohort due to cost and time considerations. The case-cohort design is efficient when exposure information is not available for the entire cohort and reduces selection bias by using a random sample of the cohort at baseline as the comparison group (20) To ensure adequate power to detect a clinically meaningful association between OPA and CHD, we randomly selected a subcohort of 6,000 participants from the eligible women at baseline (21). After the baseline examination and before December 31, 2013, a total of 4,364 CHD cases were identified. We excluded women who reported 0 years of work (189 in subcohort, 145 in cases) or had a history of nonfatal myocardial infarction (MI) or nonfatal stroke at baseline (224 in subcohort, 558 in cases). In addition, we excluded women with missing information on other covariates, including ethnicity, education, body mass index (BMI), hypertension, diabetes, and high cholesterol (328 in subcohort, 244 in cases), and those lost to follow-up (16 in subcohort, 0 in cases). The occupational data for 147 women were unclear on any of their jobs (50 in cases, 97 in subcohort) whereas an additional 298 women (37 in cases, 261 in subcohort) reported unclear information on their most recent job. After exclusions, 8,307 participants (90.8% of cases and subcohort) were included in the analysis using all assessed jobs and 8,057 participants (88.0% of cases and subcohort) were included in the analysis of most recent job. For nearly 6% of participants that did not report income, a missing indicator was assigned. Compared with those who were excluded, included participants were more likely to be White, educated, and employed in managerial or professional occupations (Supplementary Table 1).

This analysis was reviewed and approved by the institutional review board of Drexel University.

Case Ascertainment

CHD in this study included the occurrence of first MI that diagnosed based on cardiac pain, cardiac enzyme and troponin levels, and electrocardiographic findings and death from CHD (22). A local physician adjudicator verified all self-reported events through a review of medical records and death certificates. The locally verified events were then reviewed by central cardiovascular adjudicators. Although 70% of self-reported MIs were verified by the local adjudicator, the agreement between central reviews with local adjudication was 87% for MIs (22). Follow-up continued from the point at which the women entered the study until death, diagnosis of CHD, or censoring (end of follow-up or last contact).

Occupational Physical Activity Assessment

OPA variables were assessed using the Occupational Information Network (O*NET) 16.0 database (available at O*NET website: https://www.onetcenter.org/db_releases.html). On enrollment, women reported up to three paid jobs (full-time or part-time) held for the longest period since age 18. For each job, the women were asked to report the job title and industry where the job was performed, as well as the age at which work began and the total duration of employment. Trained coders at the National Institute for Occupational Safety and Health used the text responses to assign six-digit 2010 Standard Occupational Classification codes (23) to each job. A quality control coder reviewed a sample from each batch of codes.

O*NET is the main source of occupational information describing job characteristics in the United States and has been used to evaluate occupational exposure in epidemiological research (24), including several studies that extracted occupational characteristics by linking variables in O*NET corresponding to indicators of OPA to jobs identified by Standard Occupational Classification codes (25,26). On the basis of these studies, we identified four variables related to activities hypothesized to increase whole-body metabolism and cardiac output from the O*NET database: "performing general physical activities (eg, climbing, lifting, and handling of materials.), time spent sitting (reverse coded), time spent walking and running, and time spent standing" (Cronbach's $\alpha = .95$). For each six-digit Standard Occupational Classification codes, the physical activity score represents the sum of expert ratings of intensity (range: 0–100) for these four variables; higher scores indicate a higher level of intensity (less sitting and more walking or whole-body movements) of physical activity at work.

We assessed two summary measures of OPA: cumulative exposure and most recent exposure. The cumulative exposure assessed the total amount of OPA across participants' working life as the sum of the product of physical activity intensity and duration for each reported job. Most recent exposure was based on the occupation reported closest to baseline or entry into the cohort, consistent with prior research that evaluated recent OPA at the baseline of study (15–18,27).

Leisure Time Physical Activity Assessment

LTPA at baseline was measured using WHI physical activity questionnaire (28). Information on recreational walking, including walks outside the home and usual speed of walking, and other types of physical activity (strenuous, moderate, and mild), including the frequency (six categories, from 0 to 5+ days per week) and duration of each type (four categories, from <20 minutes to ≥60 minutes) were gathered from participants. Total energy expenditure per week (metabolic equivalent hours per week, MET-h/week) was calculated from the product of frequency, duration, and intensity to represent participants' LTPA (29). Approximately 68.7% variance in objective measure of activity-related energy expenditure can be captured by the self-reported physical activity (29). Evidence suggested that before retirement, recreational physical activity level was generally steady during middle and late adulthood (30). Thus, we regarded the LTPA measured at baseline as a proxy of the women's average level of LTPA in adulthood.

Statistical Analysis

Women's cumulative OPA was categorized as low, moderate, high, and very high based on the quartile distribution of the summarized score in the subcohort to evaluate the potential effect of extreme low or high OPA. Risk of CHD by OPA was estimated using Barlow's weighted Cox regression models with age as the underlying time scale to allow for overrepresentation of cases in case-cohort design (31). We calculated the sampling fraction as the proportion of subcohort size over the full cohort before exclusion (6.5%).

Confounders and mediators were selected based on prior knowledge of causal relationships between OPA and CHD (14–18). We examined univariate associations between OPA and confounders and/or mediators. After confirming that the assumption for proportional hazards was met for each covariate, we investigated the associations between the OPA and CHD in three serially adjusted models based on our understanding of the causal network linking the variables under the study: model 1 adjusted for age and ethnicity; model 2 additionally adjusted for socioeconomic position indicators: education, income, and occupational categories; and model 3 added potential mediators including history of hypertension, history of diabetes, history of hypercholesterolemia, and BMI. The independent associations of sitting, standing, walking, and general physical activity with CHD risk were additionally evaluated.

We tested additive interaction between OPA and LTPA because interaction on the additive scale is more indicative of hypothesized biological mechanisms (32). To characterize joint associations of OPA and LTPA with CHD risk, we dichotomized LTPA into low and high by the median, consistent with health-based recommendations for physical activity (33). Women with low OPA and high LTPA served as the reference group for the analysis of joint associations and were compared with the following categories: low LTPA–low OPA, low LTPA–moderate OPA, low LTPA–high OPA, low LTPA–very high OPA, high LTPA–moderate OPA, high LTPA–high OPA, high LTPA–very high OPA). We used a p value of less than .1 to test for a significant association between combined physical activity exposures and CHD incidence in previous three models.

Because the association of OPA with CHD may be attenuated after retirement, and almost half of the people in this study were retired at baseline, we conducted a sensitivity analysis to examine the association only in people who were still working at baseline. We also assessed the relationship of the combined occupational and LTPA with CHD in women who were still working at baseline given that retirement may change the patterns of LTPA (34).

For all analyses in this study, we used SAS, version 9.3 (SAS Institute, Inc., Cary, North Carolina).

Results

Compared with the subcohort, cases were older and more likely to report having low education and family income. In addition, cases had lower LTPA and higher BMI (Table 1). The distribution of characteristics in the subcohort was similar to the distribution in the whole WHI-OS cohort. Women were primarily employed in office and administrative support occupations (29%) or education-related occupations (16%). Legal (eg, lawyers) and computer occupations (eg, computer programmers and software engineers) had the lowest OPA whereas food preparation and serving-related occupations had the highest OPA (Table 2).

The levels of OPA (either cumulative or most recent) were not associated with significant increase in CHD risk after controlling for demographic factors (p *trend* = .50 for the cumulative OPA, p *trend* = .11 for the most recent OPA) and the associations were confounded by socioeconomic position (Table 3). After adjustment for socioeconomic position, the risk of CHD increased but did not reach statistical significance.

The associations of combined OPA and LTPA with CHD risk were summarized in Figure 1 (Supplementary Table 2). After adjusting for demographic and socioeconomic position, the associations of CHD with the combined measure of either the cumulative or the most recent OPA and LTPA were significant (p = .0007 for the interaction between LTPA and cumulative OPA; p = .005 for the interaction between LTPA and most recent OPA). Compared with women with low OPA and high LTPA, women with moderate to high cumulative OPA in combination with physically inactive leisure time had higher CHD risk (hazard ratio [HR]: 1.54, 95% confidence interval [CI]: 1.26, 1.88 for moderate OPA; HR: 1.46, 95% CI: 1.20, 1.78 for high OPA). Low cumulative OPA was associated with an increased risk of CHD for those sedentary during leisure time (HR: 1.40, 95% CI: 1.14, 1.71). In models evaluating most recent OPA and LTPA, the pattern was similar.

The results of analyses restricted to participants still working at baseline were similar to what we observed in the overall sample (Supplementary Table 3). We found no distinct difference in the joint associations of most recent OPA and LTPA when we limited the analysis to women who were still working at baseline (Supplementary Table 4). When the OPA indicators (sitting, standing, walking, and general physical activity) were analyzed separately, results were unchanged from the overall OPA measure (Supplementary Table 5).

Discussion

We observed no overall association between cumulative or most recent OPA and risk of CHD. Although the association of CHD with joint LTPA and OPA was significant, the increased CHD risk among women with the low level of LTPA and increasing level of OPA was primarily due to the adverse effect of low levels of LTPA.

Prior research evaluating physiological characteristics of OPA and LTPA found differential impact on CHD risk (17,35,36). Occupational physical activities are constrained and usually have a high intensity and long duration (37). Such long-term activities may lead to an overload of the cardiovascular system increasing the CHD risk (18). In contrast, exercise during leisure time involves discretionary activities. People decide their own exercise intensity and duration and have sufficient time for rest and recovery (36). By engaging in appropriate exercise, people experience a training effect that improves cardiac output and autonomic regulation, reducing the risk of CHD (36).

In accordance with our finding of no overall associations between OPA and CHD, a cohort study conducted on 45- to

Table 1. Baseline Characteristics, Comparing Coronary Heart Disease Cases, Subcohort and Full Cohort

	Case (*N* = 3,422)		Subcohort (*N* = 5,243)		Full WHI-OS cohort (*N* = 80,427)	
Characteristics	Mean (*SD*)	%	Mean (*SD*)	%	Mean (*SD*)	%
Age	67.8 (6.7)		63.5 (7.2)		63.4 (7.3)	
50–59		12.7		32.0		32.7
60–69		42.6		45.2		44.1
70–79		44.8		22.8		23.2
Ethnicity						
White[a]		87.8		86.0		85.2
Black or African American		7.4		6.8		7.2
Hispanic or Latino		2.1		3.0		3.2
American Indian or Alaskan Native		0.5		0.3		0.4
Asian or Pacific Islander		1.4		2.8		3.0
Other		0.8		1.1		1.0
Education						
High school		25.1		19.6		20.1
More than high school		74.9		80.4		79.9
Main occupation						
Managerial or professional		38.0		42.8		43.0
Technical or sales or administrative		28.8		29.1		28.2
Service or labor		18.5		16.5		16.2
Homemaker		11.0		8.1		9.3
Other		3.7		3.5		3.3
Income						
Less than $35,000		48.1		35.7		35.0
$35,000 to $49,999		18.9		18.7		19.1
$50,000 to $74,999		15.3		19.3		19.4
$75,000 or above		10.5		19.6		19.8
Do not know		7.3		6.7		6.7
BMI[b]	28.1 (6.2)		27.1 (5.7)		27.1 (5.8)	
LTPA[c]	11.9 (13.1)		13.9 (14.5)		13.9 (14.4)	
Diabetes		12.7		5.2		4.9
Hypertension		51.7		32.6		32.0
High cholesterol		20.3		13.8		13.9
Retirement		70.6		57.2		57.4

Note: BMI = Body mass index; LTPA = Leisure-time physical activity; *SD* = Standard deviation; WHI-OS = Women's Health Initiative–Observational Study.
[a]Does not include Hispanic origin.
[b]Weight (kg)/height (m)^2.
[c]Total energy expend from recreational physical activity (MET-hours/week)

64-year-old women, with 4–7 years of follow-up found that physically strenuous work was not related to CHD after adjustment for demographic factors (15). Similar findings were reported for the Copenhagen City Heart Study that included a 17.8-year follow-up of 3,032 women, aged 25–66 years old (14). This study measured OPA while women were tracked for CHD and used a combination of baseline and follow-up measures at year 5 to categorize OPA. High levels of OPA were not related to CHD even after adjustment for behavioral and clinical factors. Another case–control study of women, aged 30–60 years old, found no association of MI with OPA after adjustment for confounders (16). In contrast, one study found that moderate to high levels of OPA were associated with a reduced risk of MI among a cohort of Finnish women, aged 25–64 years, followed for 19.9 years (27). In addition, two studies reported an adverse effect of high OPA on CHD among nurses aged 45–64 years after 15 years of follow-up (17,18). However, none of these studies measured OPA objectively or considered the duration of occupational activity across women's lifetime. Misclassification of OPA status could contribute to the inconsistent findings because levels of OPA may change with job status, and the self-reported physical activity is relatively subjective and usually associated with bias (11). In addition, participants' physical activity level might differ from the average activity level if the study focused on a specific occupation (11). For instance, the physical demand for nurses is usually higher than the average female workers (37). Finally, previous studies differed in covariates considered. Ignoring the interaction between OPA and LTPA may underestimate the estimated association as the benefit provided by LTPA may counteract the potentially harmful effect of OPA.

We found the highest increased risk of CHD was among women who performed moderate to high OPA and low LTPA. Three previous studies also observed a synergistic effect of OPA and LTPA on CHD (14,15,18). In the Copenhagen City Heart Study, moderate to high OPA was associated with a reduced risk of CHD among women with moderate level of LTPA (14). In the Finnish cohort, the risk reduction by OPA was larger for women with moderate or high LTPA compared with women with low LTPA (15). Similarly, vigorous physical activity during leisure time mitigated the adverse effect of OPA on CHD risk in a cohort of nurses (18). In contrast to the three studies, our study evaluated cumulative as well as most

Table 2. Level and Distribution of Participants' Most Recent Occupation

SOC code[a]	Occupation description	%
23	Legal occupations	0.8
15	Computer and mathematical occupations	1.3
13	Business and financial operations occupations	4.6
43	Office and administrative support occupations	29.0
19	Life, physical, and social science occupations	1.6
11	Management occupations	9.1
21	Community and social service occupations	3.3
27	Arts, design, entertainment, sports, and media occupations	2.7
17	Architecture and engineering occupations	0.4
33	Protective service occupations	0.4
41	Sales and related occupations	10.4
25	Education, training, and library occupations	16.2
53	Transportation and material-moving occupations	0.8
49	Installation, maintenance, and repair occupations	0.2
29	Healthcare practitioners and technical occupations	8.8
51	Production occupations	3.1
45	Farming, fishing, and forestry occupations	0.1
31	Healthcare support occupations	1.8
39	Personal care and service occupations	2.3
47	Construction and extraction occupations	0.1
37	Building and grounds cleaning and maintenance occupations	1.1
35	Food preparation and serving-related occupations	2.0

Note: SOC=Standard Occupation Classification

[a]The occupations were ordered by occupations' average occupational physical activity level from low to very high.

Table 3. Hazard Ratios for Coronary Heart Disease Risk by Occupational Physical Activity

		Model 1[a]	Model 2[b]	Model 3[c]
OPA level	Case (*n*)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Cumulative OPA (*n* = 8,307)				
Low	839	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Moderate	748	1.10 (0.96, 1.27)	1.14 (0.98, 1.31)	1.14 (0.98, 1.32)
High	904	1.10 (0.96, 1.26)	1.14 (0.99, 1.31)	1.14 (0.98, 1.33)
Very high	877	1.07 (0.93, 1.22)	1.10 (0.95, 1.27)	1.02 (0.87, 1.19)
Most recent OPA (*n* = 8,057)				
Low	933	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Moderate	690	1.05 (0.91, 1.20)	1.10 (0.95, 1.27)	1.06 (0.92, 1.24)
High	1038	0.99 (0.97, 1.26)	1.06 (0.92, 1.21)	1.03 (0.89, 1.19)
Very high	615	1.17 (0.93, 1.26)	1.00 (0.85, 1.17)	0.97 (0.82, 1.15)

Note: CI = Confidence interval; HR = Hazard ratio; OPA = Occupational physical activity.

[a]Adjusted for age and ethnicity.

[b]Adjusted as in Model 1 and for education, income, and occupation class.

[c]Adjusted as in Model 2 and for body mass index, diabetes, cholesterol, and hypertension.

recent OPA and focused on a general population of older women rather than a population selected by occupation. Future studies are needed to explore potential dose–responses between OPA and CHD risk for people who were physically inactive during leisure time.

The use of a case-cohort design within an existing cohort allows us to efficiently assess long-term disease risk in relation to OPA; this type of direct exposure assessment and disease follow-up would take decades if conducted prospectively (20). Second, we assessed cumulative exposure through the intensity and duration of OPA in the three primary jobs held by participants since age 18. All prior studies assessed physical activity at a single point and related it to CHD risk during the follow-up period. We measured OPA by linking women's reports of occupation to standard occupational information datasets, reducing bias based on present health status and participants' own attitude.

However, the use of a job exposure matrix may underestimate the variability in exposure within the same occupation (17,18). The expert rating of OPA based on job titles may not be equal to measurements collected using technical devices, for example, accelerometers, on each participant. Further study using technical devices to assess OPA could be used to validate the measure of OPA used in this study. In addition, our results may affect by residual confounding, such as shift work resulting hours of sleep and job strain, which may be related to OPA (38,39). Our results may be influenced by the "healthy worker" bias as we included people who were working and retired at baseline. People who were able to work at baseline may have better physical conditions than those retired and lead to underestimate of the true association (40). However, our analysis for current workers

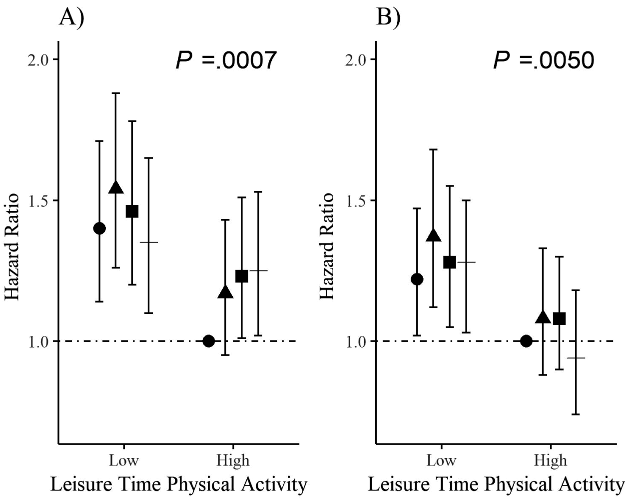

Figure 1. Hazard ratios of coronary heart disease by different levels of leisure-time physical activity and occupational physical activity. (**A**) Cumulative occupational physical activity. (**B**) Most recent occupational physical activity. Model adjusted for age, ethnicity, education, income, and occupation class. The circle represents the point estimator of low occupational physical activity. The triangle represents the point estimator moderate occupational physical activity. The square represents the point estimator high occupational physical activity. The cross represents the point estimator very high occupational physical activity.

indicated no association between OPA and CHD risk, suggesting only mild bias. Intensity of LTPA may increase after retirement (34). Using baseline LTPA as a proxy of average adulthood exposure for retired people may lead to biased estimates. Although the pattern of associations did not change after restricting the analysis to the current worker, more accurate measures of LTPA should be captured in further studies. MET levels were developed using a younger adult population and may misclassify intensity in older adults, biasing the results toward the null (41). Our participants were relatively well educated, thus our results may not generalize to women with low socioeconomic status.

In conclusion, our study suggests no overall association between OPA and CHD risk. Women with low and moderate OPA and low LTPA had an increased risk of CHD. Our study contributes to clarifying the association between OPA and CHD risk among women and reaffirms that the impact of OPA on CHD may depend on LTPA. Women are exposed to physically demanding jobs and future prevention efforts need to target on the potential adverse effect of high OPA.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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