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Associations of Work Hours, Job Strain, and Occupation with Endothelial Function: The Multi-Ethnic Study of Atherosclerosis (MESA)

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Abstract

Objective—To investigate associations of work hours, job control, job demands, job strain, and occupational category with brachial artery flow-mediated dilation (FMD) in 1,499 MESA participants.

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Methods—FMD was obtained using high-resolution ultrasound. Mean values of FMD were examined across categories of occupation, work hours, and the other exposures using regression analyses.

Results—Occupational category was significantly associated with FMD overall, with blue-collar workers showing the lowest mean values: Management/professional=4.97±0.22%; sales/office=5.19±0.28%; services=4.73 ± 0.29%; and blue-collar workers=4.01±0.26% (adjusted P <0.001). There was evidence of effect modification by gender (interaction P=0.031): significant associations were observed among women (adjusted P =0.002) and nearly significant results among men (adjusted P=0.087). Other exposures were not significantly associated with FMD.

Conclusions—Differences in endothelial function may account for some of the variation in cardiovascular disease across occupational groups.

Keywords

Brachial artery flow-mediated dilation; endothelial function; work; occupation

INTRODUCTION

The vascular endothelium is involved in numerous critical functions, including maintaining vascular homeostasis, regulating vascular tone, controlling coagulation through the production of factors that regulate platelet activity and the fibrinolytic system, and producing cytokines and adhesion molecules that regulate and direct the inflammatory process.(1, 2) Endothelial dysfunction occurs when a chronic inflammatory process is initiated, resulting in loss of vasodilator and pro-thrombotic products.(2) Endothelial dysfunction is observed in the early stages of atherosclerosis and is associated with increased plaque rupture in myocardial infarction and other adverse outcomes.(2-5) Flow-mediated dilation (FMD) of the brachial artery is a commonly used and reproducible approach to measuring endothelial function in conduit arteries.(5-7)

A large body of literature has documented the links between occupation and cardiovascular outcomes.(8-10) Effects of occupation on endothelial function could be one of the mediating pathways, but few studies have investigated how various aspects of occupation are related to endothelial function.(11) According to Cooper and colleagues (2010), participants perceiving themselves to be of lower social status in their communities exhibited reduced endothelial function (i.e., lower FMD).(11) However, the authors did not find a significant association between objective SES measures (including education/occupation) and FMD.

Other aspects of occupation that could be associated with endothelial dysfunction include shift work and work hours and psychosocial characteristics like job strain. Night-shift work has been shown to be associated with endothelial dysfunction in persons of various occupations.(12-14) Long work hours are known to be associated with multiple health conditions including cardiovascular risk factors and cardiovascular disease (CVD),(15-20) but to our knowledge associations with endothelial function have not been investigated.

Job strain has been shown to be associated with CVD outcomes.(21-24) Results from a large (n=197,473) meta-analytical study show that job strain is significantly associated with a small, but consistent, increased risk of CVD events.(23) Alterations of FMD could be one of the mechanisms through which job strain affects CVD risk,(25, 26) however, to our knowledge no studies have directly investigated whether job strain affects endothelial function.

The primary aim of this study was to determine whether long work hours, job control, job demands, job strain, and occupational categories are associated with endothelial dysfunction. Both the degree of endothelial dysfunction and work characteristics differ by gender and race.(27-29) In addition, the impact of occupational exposures on health may be modified by gender and race/ethnicity. Assessment of effect modification by these variables might help to identify the most vulnerable subgroups where the negative health impact of long work hours would be most severe. Therefore, a secondary exploratory aim of our study was to assess whether any of the relationships with FMD are modified by gender and race/ethnicity. We hypothesized that long work hours, low job control, high job demands, job strain, and being in the lower occupational categories would be positively associated with endothelial dysfunction.

METHODS

Study Design and Participants

The Multi-Ethnic Study of Atherosclerosis (MESA) was initiated in July 2000, and details of the study design and protocol have been previously published.(30) The original cohort of 6,814 men and women aged 45-84 consisted of participants from various racial and ethnic backgrounds (Whites, African-Americans, Hispanics, and Chinese Americans). The participants were recruited from six US communities (Forsyth County, North Carolina; Northern Manhattan and the Bronx, New York; Baltimore City and Baltimore County, Maryland; St. Paul, Minnesota; Chicago, Illinois; and Los Angeles, California). Persons were excluded from participating in MESA if they had any physician-diagnosed CVD or cerebrovascular disease, cancer or any serious medical condition, pregnancy, poor cognitive function, weight >300 lbs. (>136 kg), language barrier (unable to understand English, Spanish, Cantonese or Mandarin), if they lived in a nursing home, or had plans to leave the community within five years. Written informed consent was obtained from participants. The institutional review boards of the six field centers and the National Heart, Lung, and Blood Institute approved the study protocol. Approval was also obtained by the institutional review board of the National Institute for Occupational Safety and Health for secondary analysis of the study data.

Most of the data for the current study were taken from the first examination (July 2000 to July 2002). Participants were excluded from the FMD examination if they had uncontrolled hypertension (n=158), a history of Raynaud's phenomenon (n=55), a congenital abnormality of the arm or hand (n=12), a radical mastectomy on either side (n=100), or blood pressures in the left and right arms that differed by >15 mm Hg (n=307, not mutually exclusive), resulting in 6,489 participants who underwent the brachial artery FMD examination. Participants were included in these analyses if they answered “yes” to the question “do you work to earn money” (n=3700). Even though 6,489 participants had FMD measured, for cost and data quality reasons, only a subset had their tapes read and were included in the analytical dataset (n=3,025). Selection of participants for FMD reading, from those who completed the procedure at Exam 1, was performed using a case-cohort design. This included random selection of participants who completed the procedure and some of these randomly selected participants met the case definition: CVD (MI, resuscitated cardiac arrest, or CHD death, stroke, angina (definite angina or probable angina followed by revascularization)) or CHF event prior to selection (10/27/2005) (personal communication, MESA Coordinating Center). As a result, each participant had a different probability of being selected and this was accounted for during statistical analyses. We included participants if they kept the same job in both exams I and II (n=2801) and had complete values on job control, job demands, occupational category, and brachial artery FMD. The final sample size consisted of 1,499 participants, 667 women and 832 men.

Hours of Work

Participants completed questions on occupational activities. They were asked about the amount of time spent in all jobs. Number of days and hours worked per week were assessed from the question “How many days per week and hours per day do you work in all jobs?” The total number of hours of work per week was calculated by multiplying the two responses.

Occupational categories

Occupational information was collected by questionnaire.(31) Four open-ended questions modeled on the US Census occupational questions were used to determine the respondent’s current occupation: For whom do/did you work? What type of business or industry is/was this? What kind of work do/did you do? What was your job title? Participants who were no longer working were asked to respond for their last main occupation. The responses were coded using the Census 2000 Occupational Codes and categorized as follows: (1) management/professional, (2) service, (3) sales/office, (4) farming, fishing and forestry, (5) construction, extraction and maintenance, and (6) production, transportation and material moving.(31) The last three categories included a small number of participants in this sample so they were combined into one category of ‘blue-collar jobs’.

Job Demands, Job Decision Latitude, and Job Strain

At exam II (2002-2004), data were obtained for job demands and job decision latitude (a measure of job control) from the Job Content Questionnaire(32) for a subsample of participants (n=6,233) who were working at the time of data collection.(31) After straight and reverse coding, the scores were calculated following the original formulation.(33) The job control scores ranged from 24 to 96 while the job demands scores ranged from 12 to 48. Both scales had an acceptable level of internal consistency within the study sample (Cronbach’s alpha=0.70 for job demands and 0.84 for job control).(31) Job demands and job control, originally continuous variables, were both dichotomized at the sample median to create binary variables which were then combined to create the following: High job control/ high job demands, high job control/low job demands, low job control/high job demands, and low job control/low job demands. Analyses were also performed using these variables in the continuous form.

Brachial artery FMD

To assess endothelial function, brachial artery FMD was performed as one component of the first examination of the MESA cohort. Participants were required to fast for at least six hours prior to undergoing the brachial artery FMD measurement.(5, 34) A detailed description of the scanning and reading protocol can be found at the MESA Web site (www.mesa-nhlbi.org). Participants were allowed to rest for 15 minutes in the supine position. A standard blood pressure cuff was positioned around the right arm, two inches below the antecubital fossa, and the artery was imaged 5 to 9 cm above the antecubital fossa. An automated sphygmomanometer (Dinamap device) was used to monitor blood pressure and pulse in the left arm at 5-minute intervals throughout the examination. Blood pressure at baseline was measured in the left arm, before inflation of the right arm cuff, immediately before release of the occluding cuff, at 1 minute and then at 3 minutes after release of the occluding cuff. Blood pressure was measured in both arms to confirm no significant gradients (i.e., ≤15 mm Hg). This was to ensure that the maneuver did not cause a change in BP that might have affected the resting tone (diameter) of the artery.

The right brachial artery was imaged with high-resolution ultrasound at the elbow, 5 to 9 cm above the antecubital fossa, where it formed a straight segment, free of major branches. After obtaining baseline images of the right brachial artery over a 30-second period, the cuff was inflated for 5 minutes (pressure was 200 mm Hg or BP+50 mm Hg if the systolic BP was >150 mm Hg). Frame rate was fixed at 32 frames per second. Images of the right brachial artery were captured continuously for 105 seconds after cuff deflation. Videotapes of the acquired images of the brachial artery were analyzed at the Wake Forest University Cardiology Image Processing Laboratory using a previously validated semi-automated system. The readings of the digitized images generated the baseline and maximum diameters of the brachial artery from which the absolute change from baseline diameter and percentage brachial artery FMD were computed. FMD was computed with the formula: 100 (maximum – baseline diameter) / baseline diameter and expressed as a percentage.

Intrareader reproducibility was evaluated by comparing an original and a blinded quality control reread of ultrasounds from 40 MESA participants. The intraclass correlation coefficients were 0.99 for baseline diameter, 0.99 for maximum diameter, and 0.93 for % FMD. Technicians performed duplicate examinations on 19 participants on two days separated by one week to evaluate intrasubject variability. The intraclass correlation coefficients were as follows: baseline diameter (0.90), maximum diameter (0.90), and % FMD (0.54). The percent technical error of measurement for baseline diameter, maximum diameter, and % FMD measurement was 1.39%, 1.47%, and 28.4%, respectively.(5)

Covariates

Self-administered questionnaires provided information on demographic and lifestyle variables which included age, self-identified race/ethnicity, educational attainment, annual household income, pack-years of smoking for current and former smokers, and current smoking status. Height and weight were measured with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. Cigarette smoking was defined as current, former, or never. Pack-years of smoking were calculated.

Blood was drawn from participants after they had fasted for a minimum of 12 hours, and aliquots were prepared for analysis and for storage at −70 degrees F at the University of Vermont and the University of Minnesota. Laboratory analysis was performed for lipids. Low-density lipoprotein (LDL) cholesterol was calculated by the Friedewald equation.(35)

Resting blood pressure was measured three times in the seated position using a Dinamap model Pro 100 automated oscillometric sphygmomanometer (Critikon, Wipro GE Healthcare, Waukesha, Wisconsin). The average of the last two measurements was used in the analysis. Hypertension was defined as systolic pressure ≥140 mm Hg, diastolic pressure ≥90 mm Hg, or current use of antihypertensive medication.

The MESA Typical Week Physical Activity Survey (TWPAS), adapted from the Cross-Cultural Activity Participation Study,(36) was used to obtain the time and frequency spent in various physical activities during a typical week in the previous month. The survey has 28 items in categories of activity: household chores, yard/lawn/garden work, care of others (children or adults), transportation, non-occupational walking, team sports and dancing, leisure activities (e.g., reading, watching TV), work (occupational or volunteer), and intentional exercise. Participants reported the average number of days per week and time per day engaged in the activities, as well as the intensity level (light, moderate, or heavy). Minutes of activity were summed for each discrete activity type and multiplied by metabolic equivalent (MET) level to derive composite physical activity levels.

Statistical Methods

Descriptive statistics were obtained for all variables by gender, and differences between men and women were tested using the chi-square and regression analysis. We also investigated the associations of several covariates with the independent variables (hours of work, job control, job demands, and occupation) and also with the dependent variable (brachial FMD) using regression analysis. Four categories of total hours worked per week (<40, 40, 41-49, and ≥50 hours) were selected by placing participants who worked 40 hours per week into one group and then dividing the remaining hours worked to obtain reasonable and fairly equal sample sizes in each group. Job demands and job control, originally continuous variables, were both dichotomized at the sample median to create high and low categories of each variable. Mean values of brachial FMD were obtained across these categories of hours worked, job control/job demands, and occupational category. Since the sampling for FMD was not random, the inverse of the probability of selection were used as weights to account for the sampling scheme. The survey procedures in SAS were used to generate percentages, test association between categorical variables, and estimate unadjusted and adjusted means for continuous variables. P-values for trend were obtained using the continuous form of the exposure of interest. Effect modification was assessed for gender and race/ethnicity. Formal tests of effect modification were performed by including interaction terms in the fully adjusted models. Potential confounders included in the models were age, gender, race/ethnicity, educational level, plus the potentially mediating (and/or confounding) variables waist circumference, HDL cholesterol, and total cholesterol, BMI, systolic blood pressure, diastolic blood pressure, physical activity, cigarette smoking status, and pack-years of smoking. Three variables, diabetes, glucose level, and use of antihypertensive medications, when included in the multivariate models did not change the results so they were omitted from the final models. SAS version 9.2 was used to analyze these data.(37)

RESULTS

The mean age ± SEM of participants in this analysis was 56.1 ± 0.21 years (Table 1). Slightly more than half of the participants were men (n=832; 55.5%). The largest racial/ethnic group was Whites (41.2%), followed by African Americans (23.1%), Hispanics (22.5%), and Chinese Americans (13.2%). Thirty-one percent of participants worked 40 hours per week; 20.8% worked more than 50 or more hours per week. Participants were in occupations classified as management/professional (47.9%); 20.4% were in sales/office, 16.2% in service, and 15.5% in blue-collar occupational categories. Compared to women, men had significantly lower mean brachial artery FMD (4.24 ± 0.09% vs. 5.47 ± 0.13%; P <0.001).

The age-adjusted mean values of FMD across selected variables are shown in Table 2. FMD was significantly associated with race/ethnicity (lowest in African-Americans and highest in Whites) and smoking status (lowest in current smokers and highest in never smokers). FMD was negatively and significantly correlated with waist circumference, physical activity, and systolic and diastolic blood pressure; it was positively and significantly correlated with HDL and total cholesterol. Analyses were also conducted to determine the associations of demographic, lifestyle, and other characteristics with work hours, occupational categories, job demands, and job control (see online Supplemental Digital Content Table).

In Table 3, mean values of FMD are shown across categories of work hours per week, occupational categories, and job strain. There was a positive association between work hours and FMD before any risk-factor adjustment ($P = 0.001$) but the association was no longer significant after adjustment for age and gender, $P = 0.413$. After adjustment for several confounders and CVD risk factors, the association remained statistically insignificant, $P = 0.157$. FMD was significantly associated with occupational category before and after risk-factor adjustment. Employees in management/professional and sales/office categories had the highest mean FMD values, 4.97 ± 0.22% and 5.19 ± 0.28%, respectively, followed by services (4.73 ± 0.29%) and blue-collar workers (4.01 ± 0.26%) after full adjustment; P <0.001. Post-hoc comparisons revealed that the differences between management/professional and blue-collar were statistically significant (P <0.001), as were those between sales/office and blue-collar (P <0.001), and services and blue-collar ($P = 0.012$). FMD was not significantly associated with job strain, job control, or job demands after full risk-factor adjustment.

Race did not modify any of the associations between the occupational exposures and FMD (data not shown). The association between FMD and occupational category was stratified by gender and the results are shown in Table 4. Gender significantly modified the association between occupational category and FMD (interaction $P = 0.031$) but did not modify any of the other associations with FMD. Women in the management/professional and sales/office categories had the highest mean FMD values whereas those in the blue-collar group had the lowest value, and these effects were robust to various adjustments. After full risk-factor adjustment, the results among women remained statistically significant, $P = 0.002$. The association between FMD and occupational category was statistically significant among men after adjustment for age ($P = 0.042$), but not in the more fully adjusted models. Post-hoc comparisons revealed that, among women, the differences between management/professional and blue-collar were statistically significant ($P = 0.008$) as were those between sales/office and blue-collar ($P = 0.001$).

DISCUSSION

In this community-based sample of employed individuals, we examined the association of work hours, job demands, job control, job strain, and occupational category with brachial artery FMD. Occupational category was significantly associated with FMD; blue-collar workers had the lowest mean FMD value and those in the management/professional and services categories had the highest mean values. After stratification by gender, the pattern remained but the association was only significant among women.

We did not find any published studies that investigated the association between occupational category and endothelial function, but Cooper and colleagues found that participants perceiving themselves to be of lower social status in their communities exhibited reduced endothelial function (i.e., lower FMD).(11) This association remained significant after adjusting for objective SES measures such as income, education/occupation and other covariates, although they did not find a significant association between objective SES measures and FMD. The authors posited that endothelial dysfunction could be a pathway through which psychosocial factors, such as subjective social status, are linked to CVD. In contrast, among a healthy group of British civil servants, several markers of socioeconomic status such as lower employment grade, educational qualifications and income showed no relationship to any measure of vascular function, including FMD.(38) We found that blue-collar workers have significantly worse endothelial function than management/professional workers. However, this association was stronger in women than in men, suggesting the need for further research on differential effects of occupational conditions by gender.

In the present study, neither job demands, job control, nor job strain were found to be significantly association with FMD. Studies investigating the association between job strain and endothelial function were not found, but numerous articles investigating the relationship between job strain and coronary heart disease are available. One study examined the relationship between job strain, job insecurity, and incident CVD over 10 years among 22,086 participants in the Women’s Health Study.(24) Women with high job strain (high demands, low control) and active jobs (high demands, high control) were 38% more likely to experience a CVD event than those who reported low job strain. Results from the Whitehall II study, a prospective cohort study, show that men and women with low job control had a higher risk coronary heart disease during the follow-up compared with those with high job control.(21) Kivimaki and colleagues conducted a meta-analysis of published and unpublished studies and reported that job strain was significantly associated with a small, but consistent, increased risk of CVD events.(23) However, we found no evidence that job strain is related to endothelial function. Our results suggest that the effect of job strain on endothelial function is not an important pathway through which job strain is linked to cardiovascular events.

No published studies have been identified that investigated the association between work hours and FMD. However, a recent systematic review conducted by Virtanen and colleagues reported significant positive associations between longer work hours and coronary heart disease in seven of 12 studies, and positive but non-significant associations in the remaining five studies.(39) Other studies have reported that night or irregular shift work, but not extended work hours, negatively affects vascular function.(14, 39) We found no evidence that work hours are related to FMD.

In a recent study conducted on the MESA participants, significant positive associations were observed between work hours and common carotid IMT among women only, after adjustment for age, race/ethnicity, education, annual household income, and CVD-related risk factors.(40) In addition, longer hours of work were significantly associated with lower levels of ankle-brachial index, among men but not among women.(40) Carotid IMT and ankle-brachial index are used to estimate the burden of atherosclerosis, while endothelial function measured by FMD is a marker of sub-clinical vascular function which is believed to precede and accompany development of atherosclerosis.(2) We have no compelling explanation for why longer work hours was associated with subclinical disease but not with FMD in MESA. However, the smaller sample size for FMD analyses may have hampered our ability to detect small effects.

There are plausible mechanisms through which occupational category may be associated with endothelial function, and they include psychological stress and unhealthy lifestyle behaviors such as physical inactivity.(41-43) In our analyses, associations of blue-collar work with endothelial dysfunction persisted after controlling for waist circumference, HDL cholesterol, total cholesterol, BMI, diastolic blood pressure, systolic blood pressure, physical activity, smoking status, and pack-years of smoking suggesting that other mediators may be involved.

Our study has some limitations. Due to the cross-sectional study design, we are not able to determine causality or the temporal sequence of the association involving occupational category and brachial artery FMD. Exclusion of participants with uncontrolled hypertension, which is associated with both job strain and with endothelial dysfunction, may have resulted in some selection bias. The bias would be towards the null value if participants with both higher levels of endothelial dysfunction and adverse occupational exposures were excluded.

However, our study also has several strengths. The MESA dataset provided a rich resource in which to examine associations of long work hours, job control and job demands, and occupation with endothelial function, and included information on multiple factors that could potentially modify or confound the associations of interest. All technicians were centrally trained and were required to demonstrate competency in relevant procedures before being certified to perform MESA examinations. The large sample size, the geographically and ethnically diverse population, and utilization of internal and external quality control programs for all study measurements are additional strengths of this study. Other strengths include adjusting for traditional risk factors for CVD such as physical activity, blood pressure, total and HDL cholesterol, BMI, and waist circumference.

In summary, we found a significant association between occupational category and endothelial function; blue-collar workers had slightly worse endothelial function whereas workers in management/professional and services groups had slightly better endothelial function. Our results suggest that alterations of endothelial function may be one of the pathways linking occupational categories to FMD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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ABBREVIATIONS

BMI	Body mass index
CVD	Cardiovascular disease
FMD	Flow-mediated dilation
HDL	High-density lipoprotein
LDL	Low-density lipoprotein
MESA	Multi-Ethnic Study of Atherosclerosis
MET-min	Metabolic equivalent minutes

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Table 1

Demographic, lifestyle, and other characteristics of the study sample.

Characteristics	**All (n=1499)**	**Women (n=667)**	**Men (n=832)**	***P*-value**
	N (%)	**N (%)**	**N (%)**	
Hours of work per week				<0.001
< 40	504 (34.2)	268 (40.5)	236 (28.8)	
40	463 (31.0)	215 (32.3)	248 (29.9)	
41-49	211 (14.0)	78 (11.9)	133 (15.9)	
≥ 50	321 (20.8)	106 (15.4)	215 (25.4)	
Race/Ethnicity				0.512
White	569 (41.2)	252 (41.4)	317 (40.9)	
Chinese American	256 (13.2)	105 (11.9)	151 (14.3)	
African-American	339 (23.1)	160 (24.2)	179 (22.2)	
Hispanic	335 (22.5)	150 (22.4)	185 (22.5)	
Educational status				<0.001
≤ High school grad/GED	387 (25.5)	187 (27.5)	200 (23.8)	
Some College/Tech school	440 (30.2)	231 (35.5)	209 (25.6)	
Bachelor’s degree	293 (19.4)	123 (18.3)	170 (20.4)	
Graduate/professional	379 (24.9)	126 (18.7)	253 (30.2)	
Annual household income ($)				<0.001
<20k	164 (10.9)	82 (11.9)	82 (10.0)	
20-50k	514 (34.9)	276 (41.6)	238 (28.8)	
50-75k	316 (21.5)	144 (21.7)	172 (21.3)	
>75k	483 (32.8)	161 (24.8)	322 (39.9)	
Occupational categories				<0.001
Management/Professional	722 (47.9)	288 (43.4)	434 (51.8)	
Sales/Office	294 (20.4)	185 (28.7)	109 (13.2)	
Service	249 (16.2)	139 (20.0)	110 (12.8)	
Blue-collar	234 (15.5)	55 (7.8)	179 (22.2)	
Smoking status				<0.001
Never	801 (51.4)	419 (59.6)	382 (44.3)	
Former	507 (35.1)	171 (27.5)	336 (41.7)	
Current	191 (13.5)	77 (12.9)	114 (14.0)	
Job control/demand				<0.001
High control/high demand	334 (22.5)	122 (19.1)	212 (25.4)	
High control/low demand	340 (24.0)	112 (18.0)	228 (29.2)	
Low control/high demand	437 (28.4)	262 (38.0)	175 (20.0)	
Low control/low demand	381 (25.2)	166 (24.9)	215 (25.4)	
	Mean ± SEM	Mean ± SEM	Mean ± SEM	
Age (years)	56.1 ± 0.21	55.4 ± 0.30	56.7 ± 0.30	0.002
Body Mass Index (Kg/m^2)	28.2 ± 0.14	28.6 ± 0.25	27.8 ± 0.15	0.008
Waist circumference (cm)	96.8 ± 0.37	95.0 ± 0.64	98.3 ± 0.41	<0.001

Characteristics	**All (n=1499)**	**Women (n=667)**	**Men (n=832)**	***P*-value**
	N (%)	**N (%)**	**N (%)**	
Physical activity (MET min/wk)	14109.0 ± 179.6	14196.0 ± 259.5	14035.0 ± 248.8	0.654
Pack-years of smoking (ever-smokers)	10.3 ± 0.67	7.5 ± 0.64	12.6 ± 1.13	<0.001
Systolic blood pressure (mm Hg)	120.8 ± 0.50	118.7 ± 0.79	122.7 ± 0.62	<0.001
Diastolic blood pressure (mm Hg)	72.4 ± 0.27	68.4 ± 0.39	75.8 ± 0.31	<0.001
HDL cholesterol (mg/dL)	50.4 ± 0.39	56.7 ± 0.63	45.0 ± 0.39	<0.001
Total cholesterol (mg/dL)	193.9 ± 0.90	198.1 ± 1.34	190.2 ± 1.21	<0.001
Work hours (hours/week)	40.4 ± 0.40	38.5 ± 0.58	42.0 ± 0.54	<0.001
Baseline brachial artery diameter (mm)	4.28 ± 0.02	3.69 ± 0.02	4.80 ± 0.02	<0.001
Max brachial artery diameter (mm)	4.48 ± 0.02	3.88 ± 0.02	4.99 ± 0.02	<0.001
Brachial FMD (absolute)	0.20 ± 0.01	0.19 ± 0.01	0.20 ± 0.01	0.522
Brachial FMD (%)	4.81 ± 0.08	5.47 ± 0.13	4.24 ± 0.09	<0.001

All values were weighted.

P-values are for differences between men and women and were obtained from chi-square (categorical values) and Students' *t*-tests (continuous values).

Results for continuous variables are mean ± standard error of mean (SEM).

MET (Metabolic Equivalent): units are in thousands.

Table 2

Age-adjusted mean values of FMD (%) across selected characteristics.

Characteristics	FMD (%) Mean ± SEM
Race/Ethnicity	
White	5.37 ± 0.13
Chinese American	4.94 ± 0.17
African-American	3.96 ± 0.15
Hispanic	4.79 ± 0.14
P-value[*]	<0.001
Educational status	
≤ High school grad/GED	4.64 ± 0.13
Some College/Tech school	4.87 ± 0.15
Bachelor’s degree	4.89 ± 0.17
Graduate/professional	5.02 ± 0.15
P-value[‡]	0.071
Smoking status	
Never	4.93 ± 0.10
Former	4.95 ± 0.14
Current	4.30 ± 0.20
P-value[*]	0.014
Body Mass Index (Kg/m^2)	−0.0236, 0.098
Waist circumference (cm)	−0.0126, 0.029
Physical activity (MET min/wk)	−0.00002, 0.025
Pack-years of smoking (ever-smokers)	−0.0041, 0.061
Systolic Blood Pressure (mm Hg)	−0.0182, <0.001
Diastolic Blood Pressure (mm Hg)	−0.0418, <0.001
HDL cholesterol (mg/dL)	0.0185, 0.001
Total cholesterol (mg/dL)	0.0058, 0.007

Results for continuous variables are regression coefficients and *P*-values.

[*] *P*-values obtained from ANCOVA tests of differences between mean values.

[‡] *P*-values obtained from ANCOVA linear contrasts.

Table 3

Mean values of brachial FMD (%) by hours of work per week, occupational categories, and job strain.

	N	Model 1	Model 2	Model 3	Model 4
Work hours/week					
<40	504	4.44 ± 0.13	4.65 ± 0.13	4.65 ± 0.13	4.61 ± 0.24
40	463	5.07 ± 0.15	4.94 ± 0.14	4.95 ± 0.14	4.95 ± 0.25
41-50	211	4.96 ± 0.23	4.91 ± 0.22	4.87 ± 0.22	4.91 ± 0.34
≥50	321	4.96 ± 0.16	4.88 ± 0.16	4.87 ± 0.16	4.88 ± 0.28
P-value[1]		0.001	0.413	0.289	0.157
Occupational categories					
Mgt./Professional	722	4.93 ± 0.12	4.99 ± 0.11	4.96 ± 0.12	4.97 ± 0.22
Sales/Office	294	5.29 ± 0.20	5.35 ± 0.19	5.16 ± 0.18	5.19 ± 0.28
Services	249	4.69 ± 0.18	4.66 ± 0.17	4.79 ± 0.19	4.73 ± 0.29
Blue-collar	234	3.96 ± 0.17	3.96 ± 0.15	3.96 ± 0.16	4.01 ± 0.26
P-value[2]		<0.001	<0.001	<0.001	<0.001
Job strain					
HC/HD	334	5.18 ± 0.16	5.12 ± 0.15	4.92 ± 0.15	4.90 ± 0.26
HC/LD	340	4.35 ± 0.15	4.71 ± 0.16	4.66 ± 0.16	4.67 ± 0.26
LC/HD	437	5.21 ± 0.16	4.87 ± 0.16	4.97 ± 0.16	4.95 ± 0.26
LC/LD	381	4.47 ± 0.15	4.61 ± 0.14	4.69 ± 0.14	4.71 ± 0.24
P-value[2]		<0.001	0.088	0.388	0.518
Job control		−0.002, 0.673	0.008, 0.115	0.001, 0.875	−0.002, 0.673
Job demands		0.058, <0.001	0.024, 0.026	0.017, 0.104	0.016, 0.132

Job strain categories are: High control/high demands; high control/low demands; low control/high demands; low control/low demands.

Results for the categorical variables are mean ± SEM.

Results for ‘job control’ and ‘job demands’ are β-coefficients and *P*-values.

Model 1: Unadjusted.

Model 2: Adjusted for age and gender.

Model 3: Adjusted for age, gender, race/ethnicity, educational level, waist circumference, HDL cholesterol, and total cholesterol.

Model 4: Adjusted for age, gender, race/ethnicity, educational level, waist circumference, HDL cholesterol, total cholesterol, BMI, diastolic blood pressure, systolic blood pressure, physical activity, smoking status, and pack-years of smoking.

Gender was not included in any of the models for ‘occupational categories’ because gender is a significant effect modifier in the association between occupational categories and FMD % (see Table 4).

Occupational categories, Model 4:

Management/Professional vs. Sales/Office: *P*=0.801

Management/Professional vs. Services: *P*=0.771

Management/Professional vs. Blue-collar: *P* <**0.001**

Services vs. Sales/Office: *P*=0.293

Services vs. Blue-collar: *P*=**0.012**

Sales/Office vs. Blue-collar: *P* <**0.001**

[1] *P*-values were obtained from linear regression models.

[2] *P*-values were obtained from ANOVA/ANCOVA models.

Table 4

Mean values of brachial FMD (%) by four occupational categories, stratified by gender.

	Occupational categories				
	Mgt/Prof	**Sales/Office**	**Services**	**Blue-collar**	***P*-value**
Women	(*n*=288)	(*n*=185)	(*n*=139)	(*n*=55)	
Model 1	5.77 ± 0.21	5.75 ± 0.27	4.90 ± 0.24	4.23 ± 0.36	<0.001
Model 2	5.76 ± 0.20	5.92 ± 0.26	4.91 ± 0.24	4.39 ± 0.32	<0.001
Model 3	5.71 ± 0.22	5.82 ± 0.26	5.17 ± 0.26	4.28 ± 0.35	0.002
Model 4	5.73 ± 0.34	5.83 ± 0.40	5.21 ± 0.40	4.27 ± 0.44	0.002
Men	(*n*=434)	(*n*=109)	(*n*=110)	(*n*=179)	
Model 1	4.31 ± 0.12	4.41 ± 0.24	4.40 ± 0.27	3.88 ± 0.19	0.176
Model 2	4.40 ± 0.12	4.41 ± 0.23	4.37 ± 0.26	3.83 ± 0.18	0.042
Model 3	4.32 ± 0.13	4.43 ± 0.23	4.53 ± 0.28	3.87 ± 0.20	0.092
Model 4	4.32 ± 0.28	4.41 ± 0.33	4.48 ± 0.40	3.83 ± 0.33	0.087

Results are mean ± SE.

P-values were obtained from ANOVA/ANCOVA models.

Model 1: Unadjusted.

Model 2: Adjusted for age.

Model 3: Adjusted for age, race/ethnicity, educational level, waist circumference, HDL cholesterol, and total cholesterol.

Model 4: Adjusted for age, race/ethnicity, educational level, waist circumference, HDL cholesterol, total cholesterol, diastolic blood pressure, systolic blood pressure, physical activity, smoking status, and pack-years of smoking.

Interaction by gender (p=0.031) in the association between FMD % and occupational categories.

MODEL 4 (women):

Management/Professional vs. Sales/Office: *P*=0.993

Management/Professional vs. Services: *P*=0.513

Management/Professional vs. Blue-collar: *P*=**0.008**

Services vs. Sales/Office: *P*=0.320

Services vs. Blue-collar: *P*=0.100

Sales/Office vs. Blue-collar: *P*=**0.001**

MODEL 4 (men):

Management/Professional vs. Sales/Office: *P*=0.989

Management/Professional vs. Services: *P*=0.969

Management/Professional vs. Blue-collar: *P*=0.257

Services vs. Sales/Office: *P*=0.997

Services vs. Blue-collar: *P*=0.165

Sales/Office vs. Blue-collar: *P*=0.209