Published in final edited form as:
Am J Prev Med. 2009 January ; 36(1): 56–62. doi:10.1016/j.amepre.2008.09.031.

Physical Activity and High-Sensitivity C-Reactive Protein:

The Multi-Ethnic Study of Atherosclerosis

Darcy S. Majka, MD, **Rowland W. Chang, MD, MPH**, **Thanh-Huyen T. Vu, MD, PhD**, **Walter Palmas, MD**, **Dominic F. Geffken, MD, MPH**, **Pamela Ouyang, MBBS**, **Hanyu Ni, MPH, PhD**, and **Kiang Liu, PhD**

Division of Rheumatology (Majka, Chang), Department of Medicine, the Department of Preventive Medicine (Chang, Vu, Liu), the Department of Physical Medicine and Rehabilitation (Chang), Northwestern University Feinberg School of Medicine, Chicago, Illinois; Columbia University (Palmas), New York, New York; NH–Dartmouth Family Medicine Residency (Geffken), Concord, New Hampshire; Johns Hopkins University (Ouyang), Baltimore, Maryland; and the NIH (Ni), Bethesda, Maryland

Abstract

Background—Previous studies have suggested an inverse relationship between physical activity and markers of inflammation such as high-sensitivity C-reactive protein (hs-CRP). However, these were inconsistent, and few examined whether race and gender influenced the relationship. This study determined a cross-sectional association between physical activity and hs-CRP level in 6142 middle-aged white, Chinese, black, and Hispanic participants enrolled in the Multi Ethnic Study of Atherosclerosis in 2000–2002.

Methods—Combined moderate and vigorous physical activity was measured by self-reported leisure, conditioning, occupational, and household activities. ANCOVA was used to assess the association between moderate/vigorous physical activity and hs-CRP by gender and race.

Results—Hs-CRP was higher in women. Blacks had the highest hs-CRP, and Chinese participants had the lowest. Hs-CRP decreased across tertiles of moderate/vigorous physical activity in Hispanic men in models adjusted for age, education, study site, and physical activity questionnaire mode of administration (p=0.005) and further adjusted for smoking, infection, and aspirin use (p=0.020). The trend remained significant after further adjustment for BMI; blood pressure; low-density lipoprotein cholesterol; high-density lipoprotein cholesterol; diabetes; and the use of antihypertensive, statin, and diabetes medication (p=0.044). There was a downward trend in hs-CRP across tertiles of physical activity in black and white men, but the association was weaker. No clear trend was observed in any female racial/ethnic groups.

Address correspondence and reprint requests to: Darcy S. Majka, MD, Division of Rheumatology, Northwestern University, Feinberg School of Medicine, 240 East Huron M-200, Chicago IL 60611. d-majka@northwestern.edu.

No financial disclosures were reported by the authors of this paper.

Conclusions—These findings suggest that the association between moderate/vigorous physical activity and hs-CRP differs by race and gender. Further studies are needed to confirm this and to examine the mechanisms for these race and gender differences.

Introduction

In general, physical activity is deemed to have a positive effect on health status and is associated with a decreased risk of coronary heart disease (CHD).[1–4] It has been suggested that the association between physical activity and reduced CHD risk may be mediated by an anti-inflammatory effect of physical activity.[5–7] The majority of investigations[3,5–15] have found an inverse association between physical activity and high-sensitivity C-reactive protein (hs-CRP). However, a few studies[16,17] did not find any association. In some investigations,[6,10,17–19] BMI has been reported to account for a large portion of the association between physical activity and hs-CRP level. Further, Albert et al.[8] found that in men, but not women, strenuous aerobic activity was associated with lower hs-CRP levels. This finding may be of some consequence, because higher hs-CRP levels have been identified in women than in men.[8,10,20,21]

Previous studies of the associations between physical activity and hs-CRP were limited by the fact that the study populations consisted mainly of whites [3,5,11,13,14,16,17,19]. This is of importance, considering that both physical activity and CRP have been shown to vary with race/ethnicity.[10,20–23] In addition, not all previous studies examining the relationship between physical activity and hs-CRP utilized validated, detailed measures of physical activity, and most examined only the effects of leisure-time physical activity. Also, not all investigations included women, and the majority including women did not adjust for hormone use. This study investigated the association between physical activity and hs-CRP, utilizing a measure of physical activity that included leisure-time physical activity, occupation-related physical activity, and household chore–related physical activity in male and female participants enrolled in the Multi-Ethnic Study of Atherosclerosis (MESA). To our knowledge, no studies have explored whether the associations between physical activity and hs-CRP are similar for different gender and ethnic groups in a multi-ethnic cohort of men and women such as the MESA study population.

Methods

Design and Participants

Initiated in July 2000, MESA is a multicenter study investigating the prevalence, correlates, and progression of subclinical and clinical cardiovascular disease (CVD) in a population-based sample of 6814 men and women aged 45–84 years.[24] The MESA cohort is 47% men and has a racial/ethnic distribution of 38% white, 28% black, 22% Hispanic, and 12% Chinese participants. At the baseline exam in 2000–2002, participants were free from clinical CVD and cancer.[25] They were recruited from six U.S. communities: Baltimore MD, Chicago IL, Forsyth County NC, Los Angeles County CA, New York NY, and St. Paul MN.

For the study described here, the final analyzed sample included 6142 MESA participants after the exclusion of 672 participants (9.9%) without data for hs-CRP, physical activity level, or pertinent covariates such as diabetes mellitus, statin use, or hormone therapy. The MESA study was approved by IRBs at each site, and all subjects gave written, informed consent to participate.

Measurement of Physical Activity

Physical activity history was taken from the first examination of the MESA cohort performed in 2000–2002. Physical activity was measured using a questionnaire adapted from the Cross-Cultural Activity Participation Study, a community study funded under the Community Prevention Studies of the Women's Health Initiative.[26] The MESA questionnaire inquired about physical activity levels during a typical week over the last month prior to questionnaire administration. This questionnaire assessed self-reported light, moderate, and vigorous physical activity in the domains of household and outdoor chores; conditioning and sporting activities; occupational and volunteer work; and non–work-related walking. The minutes per week of these activities were multiplied by individual MET values; physical activity at light, moderate, and vigorous levels was expressed as MET-minutes per week. For these analyses, the MET-minutes for both moderate and vigorous physical activity levels were added together, and the combined total of MET-minutes was used. Subjects were classified into gender-specific physical activity tertile levels, using the physical activity values from the entire study population. Some of the MESA participants were assisted with the physical activity questionnaire by MESA staff, so an additional adjustment was made for this (described under Data Analysis).

Hs-CRP Measurement

For these analyses, hs-CRP data were taken from the first examination of the MESA cohort performed in 2000–2002. Plasma hs-CRP was measured using the Behring nephelometer II, an automated immunoanalyzer.[25] Hs-CRP was expressed in milligrams per liter (mg/L). Intra-assay coefficients of variation ranged from 2.3% to 4.4%, and inter-assay coefficients of variation ranged from 2.1% to 5.7%.

Other Measurements

Information about age, gender, ethnicity, education, and medical history was obtained by questionnaire. A history over the past 2 weeks of fever or any one of the following infections was self-reported: pneumonia, bronchitis, upper respiratory tract infection, urinary tract infection, sinusitis, or tooth infection. The use of aspirin, antihypertensive medication, statins, diabetes medication, or hormone therapy was obtained from the medical history. Height and weight were measured with participants wearing light clothing and no shoes. BMI was calculated as kg/m^2. After a participant had been seated for 5 minutes in a quiet room, resting blood pressure was measured three times in the seated position.[27] The average of the last two measurements was used in these analyses. High-density lipoprotein cholesterol (HDL-C) and glucose levels were measured from blood samples collected after a 12-hour fast. Total cholesterol, HDL-C, and low-density lipoprotein cholesterol (LDL-C) were measured. Total cholesterol was measured using a cholesterol oxidase method. HDL-C was also measured using the cholesterol oxidase method after precipitation of non–HDL-C. The calibration of these assays is regularly monitored by the CDC–National Heart, Lung, and Blood Institute (NHLBI) Lipid Standardization Program. LDL-C was calculated in plasma specimens having a triglyceride value <400 mg/dL using the Friedewald equation.[28]

The presence of diabetes was based on self-reported physician diagnosis; the use of insulin, an oral hypoglycemic agent, or both; or a fasting blood glucose value ≥126 mg/dL at the MESA baseline examination. Cigarette smoking was calculated as pack-years of smoking. Quality of the data collection was monitored by the MESA Coordinating Center and the MESA quality control committee.

Data Analysis

Descriptive characteristics were compared across tertiles of moderate/vigorous physical activity for men and women separately. Chi-square (for categorical variables) or ANOVA (for continuous variables) tests were used to assess the significance of differences in hs-CRP across moderate/vigorous physical activity levels. ANCOVA was used to assess the association between hs-CRP and moderate/vigorous physical activity, adjusting for covariates. Because of previously identified differences in both physical activity and hs-CRP by gender and race/ethnicity,[8,10,13,20,21,29] interaction terms were employed between race and physical activity as well as gender and physical activity. Based on cross-product terms of the interactions using dummy variables of gender or race (three dummy variables for four racial groups) and physical activity levels (two dummy variables for three tertiles of physical activity), the partial F-tests were applied to examine if the interactions were significant. While the interaction between gender and physical activity was not significant, the interaction between race and physical activity was significant at $p<0.05$. However, when physical activity was treated as a continuous variable, the interaction between gender and physical activity was marginally significant ($p=0.06$). Therefore, the associations between hs-CRP and moderate/vigorous physical activity were assessed separately for each gender and racial/ethnic group in the final analyses.

Multivariate adjusted means of hs-CRP for each tertile were computed using general linear models (GLMs) and were compared to the lowest tertile (referent). Linear trends across the tertiles were tested, using the significance level for coefficients for physical activity as an ordinal variable with values ranging from 1 to 3 in GLMs. Adjustment for covariates was done in a step-wise manner with initial adjustment for age, education, MESA study site, and physical activity questionnaire mode of administration. Then adjustment for potential confounders, including cigarette smoking, self-reported infection, and aspirin use, was added to the models.

In the final analyses, further adjustment was made for potential mediators, including BMI; systolic blood pressure; LDL-C; HDL-C; and the use of antihypertensive, statin, and diabetes medication. An additional adjustment was made for hormone therapy in female participants. Because the distribution of hs-CRP is skewed, sensitivity analyses were also performed with the natural logarithm of hs-CRP as the outcome. To be conservative, the Bonferroni correction for multiple comparisons was used with the p-value <0.05 divided by 8=0.00625. To further assess the role of BMI and hormone therapy on the association of physical activity and hs-CRP, models were repeated with and without BMI adjustment in each of the race- and gender-specific groups, and with and without hormone therapy adjustment in women. Models were also stratified between female hormone therapy users and non-users. All analyses were conducted in 2007 using SAS version 9.1.

Results

The study cohort was evenly distributed between men (*n*=3051) and women (*n*=3091), and the racial distribution was the same as that of the parent MESA cohort. The mean baseline age was 62.3 years for men and 63.4 years for women. Tables 1 and 2 show the differences in baseline characteristics in men and women by race, stratified by tertiles of moderate/vigorous physical activity. The majority of the baseline characteristics differed across tertiles of physical activity, and all were entered into the final race- and gender-specific groups measuring the association between moderate/vigorous physical activity and hs-CRP.

Mean hs-CRP was higher in women than in men (4.51 vs 2.91, $p<0.0001$). Hs-CRP was highest in black participants (4.62), followed by Hispanic participants (4.14); white participants (3.40); and Chinese participants (1.85; $p<0.0001$).

Unadjusted hs-CRP decreased across tertiles of moderate/vigorous physical activity in men, but the trend was not consistent in women (Tables 1 and 2). Taking into consideration the results from the interaction terms, as well as the known race and gender differences in hs-CRP in the MESA cohort and other study populations,[8,20,21,29,30] the analyses were performed separately in each of the eight race and gender groups. After adjusting for age, education, MESA study site, and physical activity questionnaire mode of administration, hs-CRP decreased across tertiles of moderate/vigorous physical activity level in Hispanic men ($p=0.005$; Table 3, Model 1). Hs-CRP also decreased across tertiles of moderate/vigorous physical activity level in Hispanic men after further adjustment for smoking, infection status, and aspirin use ($p=0.020$; Table 3, Model 2). The trend remained significant after further adjustment for BMI; systolic blood pressure; LDL-C; HDL-C; diabetes; and the use of aspirin, antihypertensive medication, statins, and diabetes medication ($p=0.044$; Table 3, Model 3). Of note is the fact that the associations between moderate/vigorous physical activity and hs-CRP in Hispanic men in Models 2 and 3 did not reach significance, using the Bonferroni-adjusted significance level of 0.00625. There was a modest significant downward trend in hs-CRP across tertiles of moderate/vigorous physical activity in black and white men after adjustment for demographic covariates, but the trend did not remain significant after further adjustment for potential confounders and mediators in Models 2 and 3. There was no association between moderate/vigorous physical activity and hs-CRP in Chinese men (Table 3). No clear trend was observed in any of the female racial/ethnic groups (Table 4).

Because the distribution of hs-CRP was not normal, the analyses were also performed using the geometric mean of hs-CRP; the findings were similar to those using the arithmetic mean (data not shown). The presence of BMI had only a minor impact on the association between moderate/vigorous physical activity and hs-CRP. For example, the coefficients and *p*-values for trend of models without and with BMI among Hispanic men were –0.61 ($p=0.044$) and –0.62 ($p=0.040$), respectively. For women, although users of hormone therapy had higher mean levels of hs-CRP than non-users, the use of hormone therapy did not have an impact on the association between moderate/vigorous physical activity and hs-CRP.

Discussion

This is the first reported examination of the association between hs-CRP and physical activity stratified by gender and multiple ethnic groups. The findings demonstrated a trend for an association between increasing physical activity and decreasing hs-CRP in Hispanic males. There was also a modest downward trend in hs-CRP across tertiles of moderate/ vigorous physical activity in black and white men, although the associations were weaker. There was no apparent association between hs-CRP level and moderate/vigorous physical activity in Chinese men or in any of the racial/ethnic groups of women.

Strengths of this study include the extensive cardiovascular risk-factor data available in the MESA cohort. The MESA study is a unique resource with its inclusion of a large percentage of male and female black, Hispanic, and Chinese participants. While there are several studies[3,5–15] examining the association between physical activity and hs-CRP level, the majority were conducted in white populations, and few were stratified by gender or race. Hs-CRP has been shown to vary by race and gender as well as by hormone therapy use.[8,10,13,20,21,29,30] Given these findings, as well as the race and gender differences in hs-CRP within the MESA cohort, it was appropriate to stratify by race and gender and adjust for hormone therapy use in female participants.

Limitations of this study include the cross-sectional study design, which precludes the ability to make determinations about a temporal relationship between moderate/vigorous physical activity level and hs-CRP. Additionally, the data for physical activity were self-reported and therefore less accurate than objective measures of physical fitness. However, the questionnaire used in the MESA study has been validated in another multi-ethnic population, the Cross-Cultural Activity Participation Study.[26,31]

The magnitude of the observed differences in hs-CRP levels across tertiles of moderate/ vigorous physical activity in the MESA male participants was comparable to the magnitude of differences reported in other study cohorts.[7,8,10,11,14,19,32] The findings reported in this study are in agreement with the identification by Albert and colleagues[8] of an inverse association between physical activity level and hs-CRP in men but not in women. Pischon et al.[18] also identified a downward trend in hs-CRP across quintiles of total physical activity in men but not in women.

Alternatively, the findings reported in this study are in contrast to those of Mora and colleagues,[19] in which there was a modest inverse association between recreational physical activity and hs-CRP level in female participants from the Women's Health Study (WHS). However, that trend was unadjusted. Additionally, participants in Mora et al.[19] had a lower median hs-CRP level (2.0) compared to the median hs-CRP level in MESA female participants (2.6). The lower hs-CRP level in the WHS participants might be explained by their younger age (mean age=54.7 years) compared to the MESA female participants (mean age=63.4 years) and by their predominantly white race. These discrepant outcomes for the association between physical activity and hs-CRP are not explained by differences in exogenous hormone use, given that Mora et al.[19] adjusted for hormone therapy use and Albert el al.[8] stratified by hormone therapy use. Likewise, there was no confounding or effect modification from hormone therapy use in these analyses.

Unlike the findings from some previous studies[6,10,17–19] that BMI accounted for a large percentage of the association between physical activity and hs-CRP, BMI was found in this study to have only a minor impact on the association between physical activity and hs-CRP. Similarly, the association between physical activity and hs-CRP was not mediated by BMI in the Pravastatin Inflammation/CRP Evaluation Study cohort.[8]

Perhaps the lack of association between hs-CRP and physical activity in women is due to lower levels of physical activity in women. In the majority of investigations, women have been found to engage in lower levels of physical activity.[33–37] Haase et al.[33] compared leisure-time physical activity in university students from 23 countries and found gender differences in the majority of populations, with an overall higher percentage of men (28% vs 19%, respectively, $p<0.0001$) being physically active at recommended levels. Additionally, 13,004 older female participants from the Canadian National Population Health Survey reported that they engaged less frequently in physical activity than older men,[38] and older women in the U.S. self-reported lower levels of physical activity than men.[39]

The findings reported herein demonstrate that the previously identified association between physical activity and hs-CRP in whites and blacks can also be demonstrated in Hispanics. In contrast, there may not be an inverse association between hs-CRP and physical activity in Chinese subjects. This difference might be due to either the lower level of hs-CRP in the Chinese participants in MESA, resulting in lower variation in hs-CRP, or the lower self-reported levels of physical activity in the Chinese participants.

One explanation for the lower reported levels of physical activity by the Chinese participants might be that two thirds of them required assistance with the questionnaire, a situation that in general leads to lower reported levels of physical activity. Perhaps additional race-related issues led to these lower reported levels. In the assessment of leisure-time physical activity in university students from various countries,[33] students from Pacific Asian countries did report a higher prevalence of inactivity compared to northwestern Europe and the U.S., but there were no Chinese participants. Previous studies have identified differences in reported physical activity level among various race groups within the U.S.[22,23,26] Crespo et al.[22] found that leisure-time inactivity was lower among whites (18%) than blacks (35%) and Mexican Americans (40%). Among 1422 diabetics, blacks were less likely to engage in leisure-time physical activity compared to whites, but Hispanics did not differ from whites.[23] While these cited studies have differing measures of physical activity levels and variable results, it does seem clear that race influences self-reported physical activity levels and therefore might influence the relationship between physical activity and hs-CRP. Further evaluations in multi-ethnic study populations are needed to confirm these findings and to evaluate their importance to clinical and population health.

Acknowledgments

This research was supported by NIH grants K12 RR017707 from the National Center for Research Resources and P60 AR48098 from the National Institute of Arthritis, Musculoskeletal and Skin Diseases, as well as contracts N01-HC-95159 through N01-HC-95166 from the National Heart, Lung, and Blood Institute (NHLBI). NHLBI provided funding for the MESA study and the initial design. The initial design was later modified substantially by investigators. NHLBI participated in the review of an early version of this MESA manuscript.

The authors thank the other investigators, the staff, and the participants of the MESA study for their valuable contributions. A full list of participating MESA investigators and institutions can be found at www.mesa-nhlbi.org.

References

1. Berlin JA, Colditz GA. A meta-analysis of physical activity in the prevention of coronary heart disease. Am J Epidemiol. 1990; 132(4):612–28. [PubMed: 2144946]
2. Folsom AR, Arnett DK, Hutchinson RG, Liao F, Clegg LX, Cooper LS. Physical activity and incidence of coronary heart disease in middle-aged women and men. Med Sci Sports Exerc. 1997; 29(7):901–9. [PubMed: 9243489]
3. Rothenbacher D, Hoffmeister A, Brenner H, Koenig W. Physical activity, coronary heart disease, and inflammatory response. Arch Intern Med. 2003; 163(10):1200–5. [PubMed: 12767957]
4. Sesso HD, Paffenbarger RS Jr, Lee IM. Physical activity and coronary heart disease in men: the Harvard alumni health study. Circulation. 2000; 102(9):975–80. [PubMed: 10961960]
5. Abramson JL, Vaccarino V. Relationship between physical activity and inflammation among apparently healthy middle-aged and older U.S. adults. Arch Intern Med. 2002; 162(11):1286–92. [PubMed: 12038947]
6. Kasapis C, Thompson PD. The effects of physical activity on serum C-reactive protein and inflammatory markers: a systematic review. J Am Coll Cardiol. 2005; 45(10):1563–9. [PubMed: 15893167]
7. Wannamethee SG, Lowe GD, Whincup PH, Rumley A, Walker M, Lennon L. Physical activity and hemostatic and inflammatory variables in elderly men. Circulation. 2002; 105(15):1785–90. [PubMed: 11956120]
8. Albert MA, Glynn RJ, Ridker PM. Effect of physical activity on serum C-reactive protein. Am J Cardiol. 2004; 93(2):221–5. [PubMed: 14715354]
9. Ford ES. Does exercise reduce inflammation? Physical activity and C-reactive protein among U.S. adults. Epidemiology. 2002; 13(5):561–8. [PubMed: 12192226]
10. Geffken DF, Cushman M, Burke GL, Polak JF, Sakkinen PA, Tracy RP. Association between physical activity and markers of inflammation in a healthy elderly population. Am J Epidemiol. 2001; 153(3):242–50. [PubMed: 11157411]
11. Koenig W, Sund M, Frohlich M, et al. C-reactive protein, a sensitive marker of inflammation, predicts future risk of coronary heart disease in initially healthy middle-aged men: results from the MONICA (Monitoring Trends and Determinants in Cardiovascular Disease) Augsburg Cohort Study, 1984 to 1992. Circulation. 1999; 99(2):237–42. [PubMed: 9892589]
12. Panagiotakos D, Pitsavos C, Chrysohoou C, Kavouras S, Stefanadis C. The associations between leisure-time physical activity and inflammatory and coagulation markers related to cardiovascular disease: the ATTICA Study. Prev Med. 2005; 40:432–7. [PubMed: 15530595]
13. Pitsavos C, Chrysohoou C, Panagiotakos DB, et al. Association of leisure-time physical activity on inflammation markers (C-reactive protein, white cell blood count, serum amyloid A, and fibrinogen) in healthy subjects (from the ATTICA study). Am J Cardiol. 2003; 91(3):368–70. [PubMed: 12565104]
14. Tomaszewski M, Charchar FJ, Przybycin M, et al. Strikingly low circulating CRP concentrations in ultramarathon runners independent of markers of adiposity: how low can you go? Arterioscler Thromb Vasc Biol. 2003; 23(9):1640–4. [PubMed: 12869354]
15. Colbert LH, Visser M, Simonsick EM, et al. Physical activity, exercise, and inflammatory markers in older adults: findings from the Health, Aging and Body Composition Study. J Am Geriatr Soc. 2004; 52(7):1098–1104. [PubMed: 15209647]

16. Verdaet D, Dendale P, De Bacquer D, Delanghe J, Block P, De Backer G. Association between leisure time physical activity and markers of chronic inflammation related to coronary heart disease. Atherosclerosis. 2004; 176(2):303–10. [PubMed: 15380453]
17. Rawson ES, Freedson PS, Osganian SK, Matthews CE, Reed G, Ockene IS. Body mass index, but not physical activity, is associated with C-reactive protein. Med Sci Sports Exerc. 2003; 35(7): 1160–6. [PubMed: 12840637]
18. Pischon T, Hankinson SE, Hotamisligil GS, Rifai N, Rimm EB. Leisure-time physical activity and reduced plasma levels of obesity-related inflammatory markers. Obes Res. 2003; 11(9):1055–64. [PubMed: 12972675]
19. Mora S, Lee IM, Buring JE, Ridker PM. Association of physical activity and body mass index with novel and traditional cardiovascular biomarkers in women. JAMA. 2006; 295(12):1412–9. [PubMed: 16551713]
20. Khera A, McGuire DK, Murphy SA, et al. Race and gender differences in C-reactive protein levels. J Am Coll Cardiol. 2005; 46(3):464–9. [PubMed: 16053959]
21. Anand SS, Razak F, Yi Q, et al. C-reactive protein as a screening test for cardiovascular risk in a multiethnic population. Arterioscler Thromb Vasc Biol. 2004; 24(8):1509–15. [PubMed: 15205215]
22. Crespo CJ, Smit E, Andersen RE, Carter-Pokras O, Ainsworth BE. Race/ethnicity, social class and their relation to physical inactivity during leisure time: results from the Third National Health and Nutrition Examination Survey, 1988–1994. Am J Prev Med. 2000; 18(1):46–53. [PubMed: 10808982]
23. Egede LE, Poston ME. Racial/ethnic differences in leisure-time physical activity levels among individuals with diabetes. Diabetes Care. 2004; 27(10):2493–4. [PubMed: 15451923]
24. Bild DE, Bluemke DA, Burke GL, et al. Multi-ethnic study of atherosclerosis: objectives and design. Am J Epidemiol. 2002; 156(9):871–81. [PubMed: 12397006]
25. Lakoski SG, Cushman M, Palmas W, Blumenthal R, D's Agostino RB Jr, Herrington DM. The relationship between blood pressure and C-reactive protein in the Multi-Ethnic Study of Atherosclerosis (MESA). J Am Coll Cardiol. 2005; 46(10):1869–74. [PubMed: 16286174]
26. Ainsworth BE, Irwin ML, Addy CL, Whitt MC, Stolarczyk LM. Moderate physical activity patterns of minority women: the Cross-Cultural Activity Participation Study. J Womens Health Gend Based Med. 1999; 8(6):805–13. [PubMed: 10495261]
27. Ramsey M 3rd. Blood pressure monitoring: automated oscillometric devices. J Clin Monit. 1991; 7(1):56–67. [PubMed: 1999699]
28. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem. 1972; 18(6):499–502. [PubMed: 4337382]
29. Ford ES, Giles WH, Myers GL, Rifai N, Ridker PM, Mannino DM. C-reactive protein concentration distribution among U.S. children and young adults: findings from the National Health and Nutrition Examination Survey, 1999–2000. Clin Chem. 2003; 49(8):1353–7. [PubMed: 12881452]
30. Langer RD, Pradhan AD, Lewis CE, et al. Baseline associations between postmenopausal hormone therapy and inflammatory, haemostatic, and lipid biomarkers of coronary heart disease. The Women’s Health Initiative Observational Study Thromb Haemost. 2005; 93(6):1108–16.
31. Whitt MC, Levin S, Ainsworth BE, Dubose KD. Evaluation of a two-part survey item to assess moderate physical activity: the Cross-Cultural Activity Participation Study. J Womens Health (Larchmt). 2003; 12(3):203–12. [PubMed: 12804350]
32. Rohde LE, Hennekens CH, Ridker PM. Survey of C-reactive protein and cardiovascular risk factors in apparently healthy men. Am J Cardiol. 1999; 84(9):1018–22. [PubMed: 10569656]
33. Haase A, Steptoe A, Sallis JF, Wardle J. Leisure-time physical activity in university students from 23 countries: associations with health beliefs, risk awareness, and national economic development. Prev Med. 2004; 39(1):182–90. [PubMed: 15208001]
34. Lee YS. Gender differences in physical activity and walking among older adults. J Women Aging. 2005; 17(1-2):55–70. [PubMed: 15914419]

35. Marquez DX, McAuley E. Gender and acculturation influences on physical activity in Latino adults. Ann Behav Med. 2006; 31(2):138–44. [PubMed: 16542128]
36. Trost SG, Pate RR, Dowda M, Saunders R, Ward DS, Felton G. Gender differences in physical activity and determinants of physical activity in rural fifth grade children. J Sch Health. 1996; 66(4):145–50. [PubMed: 8683949]
37. Wu TY, Rose SE, Bancroft JM. Gender differences in health risk behaviors and physical activity among middle school students. J Sch Nurs. 2006; 22(1):25–31. [PubMed: 16435927]
38. Kaplan MS, Newsom JT, McFarland BH, Lu L. Demographic and psychosocial correlates of physical activity in late life. Am J Prev Med. 2001; 21(4):306–12. [PubMed: 11701302]
39. CDC. Prevalence of health care providers asking older adults about their physical activity levels—U.S., 1998. MMWR Morb Mortal Wkly Rep. 2002; 51(19):412–4. [PubMed: 12033477]

Table 1

Selected characteristics of 3051 MESA men by tertiles of MET-minutes of moderate/vigorous physical activity per week

Characteristics (unit)[a]	Moderate/vigorous physical activity (MET-minutes/week)			
	Tertile 1 (0–<2760)	Tertile 2 (2760–<6690)	Tertile 3 (6690–103,320)	*p*-value[b]
n	1000	1012	1039	
Age (years)	64.7 (9.9)	63.0 (10.3)***	59.2 (9.8)***	<0.001
Race (%)				<0.001
White	35.6	44.8***	36.9	
Chinese	18.3	12.6***	6.4***	
Black	24.1	25.3	28.8**	
Hispanic	22.0	17.4***	27.9***	
Education (%)				<0.001
≤High school	35.4	24.6***	33.1	
Some college	21.1	25.6**	34.5***	
≥College	43.5	49.8***	32.4***	
MESA study site (%)				<0.001
Forsyth County NC	13.3	14.9	17.8***	
New York NY	15.6	14.5	15.8	
Baltimore MD	14.5	13.9	16.1	
St. Paul MN	10.0	15.4***	23.5***	
Chicago IL	17.8	22.0**	13.0***	
Los Angeles County CA	28.8	19.2***	13.9***	
Physical activity questionnaire mode of administration				
Self-administered (%)	57.0	72.5***	76.6***	<0.001
Pack-years cigarette smoking	17.3 (28.0)	14.0 (29.4)***	13.7 (21.8)***	0.003
Self-reported infection (%)	23.9	19.8**	20.6*	0.057
BMI (kg/m^2)	27.7 (4.8)	27.7 (4.3)	28.1 (4.2)*	0.050
SBP (mmHg)	127.7 (20.2)	125.6 (19.5)**	124.4 (18.2)***	<0.001

Characteristics (unit)[a]	Moderate/vigorous physical activity (MET-minutes/week)			
	Tertile 1 (0–<2760)	**Tertile 2 (2760–<6690)**	**Tertile 3 (6690–103,320)**	***p*-value[b]**
LDL-C (mg/dL)	114.3 (30.8)	116.1 (29.7)	119.8 (32.4)***	<0.001
HDL-C (mg/dL)	44.8 (11.5)	45.9 (12.0)*	45.0 (11.7)	0.714
Diabetes (%)	18.8	13.9***	13.5***	0.001
Antihypertensive use (%)	41.7	36.5**	28.7***	<0.001
Statin use (%)	15.4	15.9	13.0	0.138
Diabetes medication use (%)	13.2	9.5***	8.8***	0.002
Aspirin use (%)	29.0	30.3	23.7***	0.002
hs-CRP (mg/L)	3.4 (7.2)	2.8 (4.7)	2.5 (4.4)	<0.001

[a] Numbers are M(SD) unless otherwise indicated.

[b] *p* -value for linear trend (based on linear regression models) for continuous variables and for the overall group comparison based on χ^2 tests (for categorical variables)

* $p < 0.1$;

** $p < 0.05$;

*** $p < 0.01$ for comparisons between the tertiles relative to the ref (Tertile 1 or lowest level) HDL-C, high-density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol; MESA, Multi-Ethnic Study of Atherosclerosis; mg/dL, milligrams per deciliter; mg/L, milligrams per liter; SBP, systolic blood pressure

Table 2

Selected characteristics of 3091 MESA women by tertiles of MET-minutes of moderate/ vigorous physical activity per week

	Moderate/vigorous physical activity (MET-minutes/week)			
Characteristics (unit)[a]	**Tertile 1 (0–<2295)**	**Tertile 2 (2295–<5333)**	**Tertile 3 (5333–41,400)**	***p*-value**[b]
n	1014	1027	1050	
Age (years)	65.6 (9.8)	64.1 (9.5)***	60.6 (9.2)***	<0.001
Race (%)				<0.001
White	31.1	44.8***	38.6***	
Chinese	16.9	10.9***	6.6***	
Black	26.7	25.5	34.6***	
Hispanic	25.4	18.8***	20.3***	
Education (%)				<0.001
≤High school	50.6	37.8***	35.5***	
Some college	23.6	30.0***	35.7***	
≥College	25.8	32.2***	28.8	
MESA study site (%)				<0.001
Forsyth County NC	16.4	18.1	16.5	
New York NY	12.7	16.8**	20.9***	
Baltimore MD	13.2	15.2	16.6**	
St. Paul MN	12.5	14.0	19.0***	
Chicago IL	16.5	19.2	17.2	
Los Angeles County CA	28.7	16.8***	9.9***	
Physical activity questionnaire mode of administration				
Self-administered (%)	50.6	70.4***	79.4***	<0.001
Pack-years cigarette smoking	9.3 (19.4)	8.8 (17.0)	7.8 (16.5)*	0.064
Self-reported infection (%)	26.7	26.3	26.7	0.971
BMI (kg/m^2)	29.0 (6.3)	28.3 (6.2)**	28.7 (5.9)	0.350
SBP (mmHg)	131.4 (24.2)	127.6 (23.6)***	125.7 (22.2)***	<0.001
LDL-C (mg/dL)	117.5 (33.3)	116.2 (31.1)	120.9 (31.3)**	0.012
HDL-C (mg/dl)	54.9 (14.2)	57.7 (15.7)***	56.9 (15.5)***	<0.001
Diabetes (%)	16.4	11.9***	11.2	<0.001
Antihypertensive use (%)	43.7	40.9	36.7***	0.005
Statin use (%)	19.5	15.2***	13.6***	<0.001
Diabetes medication use (%)	12.3	7.7***	7.9***	<0.001
Aspirin use (%)	23.6	23.1	17.6***	0.001
HT use (%)	28.2	34.5***	32.3**	0.009

	Moderate/vigorous physical activity (MET-minutes/week)			
Characteristics (unit)[a]	**Tertile 1 (0–<2295)**	**Tertile 2 (2295–<5333)**	**Tertile 3 (5333–41,400)**	***p*-value**[b]
hs-CRP (mg/L)	4.9 (6.2)	4.1 (5.3)**	4.5 (5.8)	0.166

[a]Numbers are M(SD) unless otherwise indicated.

[b]*p* -value for linear trend (based on linear regression models) for continuous variables and for the overall group comparison based on χ^2 tests (for categorical variables)

*$p < 0.1$;

**$p < 0.05$;

***$p < 0.01$ for comparisons between the tertiles relative to the ref (Tertile 1 or lowest level) HDL-C, high-density lipoprotein cholesterol; HT, hormone therapy; hs-CRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol; MESA, Multi-Ethnic Study of Atherosclerosis; mg/dL, milligrams per deciliter; mg/L, milligrams per liter; SBP, systolic blood pressure

Table 3

Adjusted[a] M hs-CRP in MESA men across tertiles of MET-minutes/week of moderate/vigorous physical activity

	Moderate/vigorous physical activity (MET-minutes/week)			
	Tertile 1 (<2760)	**Tertile 2 (2760–<6690)**	**Tertile 3 (≥6690)**	***p* for trend[b]**
Number of participants				
White	356	453	383	
Chinese	183	127	66	
Black	241	256	300	
Hispanic	220	176	290	
n	1000	1012	1039	
Model 1				
White	2.66	2.50	2.06**	0.040
Chinese	1.95	1.58	1.98	0.905
Black	4.38	3.43	3.16**	0.049
Hispanic	4.56	3.51*	2.83***	0.005
Model 2				
White	2.58	2.54	2.08*	0.080
Chinese	1.96	1.60	1.91	0.839
Black	4.36	3.43	3.18*	0.057
Hispanic	4.36	3.56	2.95**	0.020
Model 3				
White	2.54	2.58	2.08	0.106
Chinese	1.93	1.67	1.86	0.868
Black	4.32	3.32	3.30*	0.106
Hispanic	4.23	3.63	3.02**	0.044

[a]Model 1: adjusted for age, education, MESA study site, and physical activity questionnaire mode of administration; Model 2: further adjusted for pack-years of cigarette smoking, infection status, and aspirin use; Model 3: further adjusted for BMI; blood pressure; low-density lipoprotein cholesterol; high-density lipoprotein cholesterol; diabetes; and the use of antihypertensive, statin, and diabetes medication

[b]*p*-values for trend in hs-CRP across tertiles of moderate/vigorous physical activity

* $p<0.1$;

** $p<0.05$;

*** $p<0.01$ for comparisons with Tertile 1 (lowest level) based on general linear models hs-CRP, high-sensitivity C-reactive protein; MESA, Multi-Ethnic Study of Atherosclerosis

Table 4

Adjusted[a] M hs-CRP in MESA women across tertiles of MET-minutes/week of moderate/vigorous physical activity

	Moderate/vigorous physical activity (MET-minutes/week)			
	Tertile 1 (<2295)	**Tertile 2 (2295–<5333)**	**Tertile 3 (≥5333)**	***p* for trend[b]**
Number of participants				
White	315	460	405	
Chinese	171	112	69	
Black	271	262	363	
Hispanic	257	193	213	
n	1014	1027	1050	
Model 1				
White	5.22	4.04***	4.20**	0.036
Chinese	2.11	1.76	1.46	0.124
Black	6.50	5.04**	5.12**	0.016
Hispanic	4.92	4.87	4.45	0.366
Model 2				
White	5.21	4.04***	4.21**	0.041
Chinese	2.05	1.81	1.54	0.222
Black	6.44	5.05**	5.15**	0.026
Hispanic	4.90	4.94	4.40	0.350
Model 3				
White	4.89	4.04**	4.45	0.381
Chinese	2.06	1.76	1.60	0.247
Black	6.42	4.87***	5.30**	0.049
Hispanic	4.72	4.94	4.62	0.862

[a]Model 1: adjusted for age, education, MESA study site, and physical activity questionnaire mode of administration; Model 2: further adjusted for pack-years of cigarette smoking, infection status, and aspirin use; Model 3: further adjusted for BMI; blood pressure; low-density lipoprotein cholesterol; high-density lipoprotein cholesterol; diabetes; the use of antihypertensive, statin, and diabetes medication; and hormone therapy

[b]*p*-values for trend in hs-CRP across tertiles of moderate/vigorous physical activity

* $p<0.1$;

** $p<0.05$;

*** $p<0.01$ for comparisons with Tertile 1 (lowest level) based on general linear models hs-CRP, high-sensitivity C-reactive protein; MESA, Multi-Ethnic Study of Atherosclerosis