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Gender Differences in C - reactive protein and Muscle Strengthening Activity

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Abstract

PURPOSE—We sought to examine the gender differences between C-reactive protein (CRP) and muscle strengthening activity (MSA) in U.S. adults (≥20 years of age).

METHODS—The sample (n=9,135) included participants in the 1999–2004 National Health and Nutrition Examination Survey (NHANES). Three categories of reported MSA participation were created: no MSA (referent group), some MSA (≥1 to <2 days/week), and meeting the 2008 Department of Health and Human Services (DHHS) recommendation (≥2 days/week). The dependent variable was elevated CRP (>3 to 10 mg/L).

RESULTS—Gender stratified analysis revealed significantly lower odds of having elevated CRP for women reporting some MSA (OR 0.61; 95% CI 0.45–0.83, P=0.0023), or volumes of MSA meeting the DHHS recommendation (OR 0.66; 95% CI 0.54–0.82, P=0.0004). Significantly lower odds of men having elevated CRP was observed in those reporting MSA volumes meeting the recommendation (OR 0.73; 95% CI 0.61–0.88, P=0.0011). Following adjustment for WC these odds remained significant in men but not women.

CONCLUSIONS—Women reporting any MSA were found to have lower odds of having elevated CRP when compared to those reporting no MSA prior to adjustment for WC. Significantly lower odds in men were only observed in those meeting the recommendation. These results suggest that WC may mediate the associations between MSA and CRP and this relationship may be stronger in women.

Keywords

INFLAMMATION; EXERCISE; PHYSICAL ACTIVITY; NHANES; SEX

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Introduction

Elevated levels of C-reactive protein (CRP), a non-specific marker of inflammation, have been shown to be associated with an increase in risk of cardiovascular disease (CVD) (3). Moreover, previous cross-sectional analyses have revealed statistically significant positive associations between CRP concentrations and self-reported myocardial infarction (15) and stroke (16). It has also been shown that physical activity (PA) participation has a role in reducing incidence of CVD (27). Although PA may produce a short term rise in circulating levels of CRP, long term participation in exercise training has been shown to reduce CRP levels (22). Some studies have suggested that the associations between PA and CVD may be mediated by inflammation (26, 36).

The Department of Health and Human Services (DHHS) 2008 Physical Activity Guidelines for Americans recommend that adults should do muscle-strengthening activities (MSA) that are moderate or high intensity and involve all major muscle groups on two or more days/ week because MSA provides additional benefits not found with aerobic activity (2). The benefits of MSA include increased bone strength, muscular fitness, and help maintaining muscle mass during a program designed to promote weight loss (2). Studies have also shown that protocols utilizing MSA are effective in decreasing circulating levels of CRP (13, 20, 32). However, there are few gender-stratified studies analyzing the distribution of elevated CRP (>3 mg/L), or the relationship between PA and CRP, and the limited current literature has revealed mixed results (4, 7, 17, 21, 23, 25). The purpose of this study is to examine the associations between self-reported MSA and CRP in adult participants of the National Health and Nutrition Examination Survey (NHANES) when stratified by gender.

Methods

This study utilized six years of data from the 1999–2004 NHANES, a continuous survey conducted by the National Center for Health Statistics (9). The NHANES is designed to provide national estimates of the health and nutritional status of non-institutionalized United States (U.S.) civilians over the age of two months. The overall response rates ranged from 76% to 80% for participants selected for examination in the 1999–2004 NHANES. The total 1999–2004 NHANES sample size was 31,126, ages two months and above. A total of 15,332 adults (≥20 years of age) provided responses to the interview portion of 1999–2004 NHANES. Following the exclusion of 833 pregnant women and 16 adults with missing responses related to MSA participation a total of 14,483 participants were available for further analysis. Of these participants, 12,643 adults (87%) attended a mobile examination center and provided the serum necessary for the measurement of CRP. Following the exclusion of adults with any missing values for other study covariates, the final sample consisted of 4,079 male and 5,056 female U.S. adults. The testing and examination procedures were approved by the institutional review board of the National Center for Health Statistics and all participants provided informed consent (10). Use of the NHANES data was approved by the University of North Florida Institutional Review Board.

The primary independent variable in this study was frequency of participation in MSA activities and was calculated from 'self-reported' MSA patterns. The final sample provided responses to the following items which came from the physical activity questionnaire file item PAD440: *Over the past 30 days, did {you/SP} do any physical activities specifically designed to strengthen {your/his/her} muscles such as lifting weights, push-ups or sit-ups? Include all such activities even if you have mentioned them before in the past 12 months.* The sample also provided responses to PA questionnaire file item PAD460: *Over the past 30 days, how often did you do these activities? [Activities designed to strengthen {your/his/her} muscles such as lifting weights, push-ups or sit-ups.]* The MSA variable was created with three categories: no MSA, some MSA, and meeting the DHHS recommendations. No MSA was coded as 0 days/week, some MSA as ≥1 to <2 days/week, and meeting the recommendation as ≥2 days/week.

Four categories of race were created: non-Hispanic White, non-Hispanic Black, Mexican American, and other. Serum cotinine, a metabolite of nicotine that is used as a marker for active smoking and environmental tobacco smoke exposure, was dichotomized (yes/no) based on having a serum level ≥3 ng/mL (6). Non-high density lipoprotein cholesterol (non-HDL-C) was calculated by subtracting HDL-C from total cholesterol and divided into four categories: <130, 130 to <160, 160 to <190, and ≥190 mg/dL based on goals recommended in the Third Report of the National Education Program Adult Treatment Panel III (NCEP ATP III) (1). Reduced HDL-C, based on the NCEP ATP III and American Heart Association/National Heart, Lung, and Blood Institute (AHA/NHLBI) definitions, was dichotomized (yes/no) for men (<40 mg/dL or drug treatment) and women (<50 mg/dL or drug treatment) (1, 18). Glycohemoglobin (HbA1c %) was divided into three categories based on American Diabetes Association (ADA) recommendations for diagnosis of diabetes mellitus: <5.7%, 5.7 to 6.4%, and >6.4% (5). Hypertension (systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg or current antihypertensive drug treatment) was dichotomized (yes/no) using the NCEP ATP III definition (1). A dichotomous hormone therapy variable (yes/no) was created for women based on responses to the following item from the reproductive health questionnaire file item RHQ540: *{Have you/Has SP} ever used female hormones such as estrogen and progesterone? Please include any forms of female hormones, such as pills, cream, patch, and injectables, but do not include birth control methods or use for fertility*. Lastly, waist circumference (WC), which was measured using steel tape just above the uppermost lateral border of the right ilium to the nearest millimeter, was examined continuously in order to examine the odds of having an elevated CRP concentration for every centimeter increment of WC.

The dependent variable in this study was elevated CRP (>3 to10 mg/L) (28). Tests with a CRP level of >10 mg/L are often due to acute conditions, and recommendations are to exclude such tests (28). C-reactive protein concentrations were measured using latex-enhanced nephelometry (Dade Behring Nephelometer II Analyzer System) at the University of Washington Medical Center in Seattle, Washington.

The data in this study were initially managed using SAS 9.2 (31). SAS was used to conduct both complex variable recodes and data coding validation. SAS-callable SUDAAN (29) was then used to conduct the analysis, incorporating sampling weights within the context of the

complex multistage sampling design inherent to NHANES. Following a forward selection process based on Wald F-test results, gender-specific best fit models were constructed. The resultant logistic regression models for men included the following covariates: HDL-C, non-HDL-C, HbA1c %, hypertension, serum cotinine, and WC. Best fit logistic regression models for women included the following covariates: race, non-HDL-C, hormone therapy, and WC. Possible effect modification by gender or MSA participation was tested by adding an interaction term to the logistic regression models.

Results

Table 1 illustrates the prevalence estimates for elevated CRP in U.S. adults according to sample characteristics.

The age-adjusted prevalence of elevated CRP levels among U.S. adult men and women was 24.4% and 36.0%, respectively (Table 1). The prevalence of elevated CRP increased with age in both men and women and was higher among Mexican Americans and non-Hispanic blacks. Prevalence of elevated CRP was also increased in those with serum cotinine concentrations >3 ng/mL. When examined by non-HDL-C concentration, the prevalence of elevated CRP was shown to increase with increasing non-HDL-C concentration. The adjusted prevalence of elevated CRP concentrations was also increased in those with glycohemoglobin range from 5.7 to <6.5%, or ≥6.5%. The prevalence of elevated CRP was also increased in men and women with an augmented WC, 36.4% and 50.4%, respectively.

The interaction term for gender and MSA participation in the multiple logistic regression model was not significant (P=0.3063), thus the term was not included in the resultant models. Tables 2 and 3 illustrate the results of the logistic regression analyses examining the associations between elevated CRP concentrations and MSA.

Crude analysis revealed significantly lower odds of having an elevated CRP level for male participants reporting some MSA (OR 0.65; CI 0.46–0.92, P=0.0162), or volumes meeting the DHHS recommendation (OR 0.57; 0.49–0.67, P<0.0001) when compared to a referent group reporting no MSA (Table 2). Crude analysis also revealed significantly lower odds of having an elevated CRP level for female participants reporting some MSA (OR 0.49; CI 0.36–0.67, P<0.0001), or volumes meeting the DHHS recommendation (OR 0.62; CI 0.51–0.75, P<0.0001) when compared to a referent group of females reporting no MSA (Table 3). Following adjustment for select demographic and metabolic risk factors, the odds of having an elevated CRP level were 27% and 34% lower (P<0.01) in male and female U.S. adults meeting the DHHS recommendation, respectively (Tables 2 & 3, Model 2). Following adjustment for WC these odds were no longer statistically significant in women (Table 3, Model 3). In contrast, the attenuated odds of elevated CRP remained statistically significant in those reporting volumes of MSA meeting the DHHS recommendation (OR 0.77; CI 0.63–0.95, P=0.0148) (Table 2, Model 3).

Compared to their respective referent groups with non-HDL-C levels <130 mg/dL, men and women with non-HDL-C levels 160 to <190 mg/dL, or ≥190 mg/dL, were significantly more likely (P<0.05, all models) to have an elevated CRP level. However, the increased odds of

having an elevated CRP level in men with non-HDL-C concentrations 130 to <160 mg/dL were not statistically significant. Men with low HDL-C concentrations (<40 mg/dL) or elevated serum cotinine concentrations (≥3 ng/mL) were significantly more likely to have an elevated CRP level (P<0.05, all models). Having an HbA1c concentration of 5.7 to 6.4% or hypertension was also associated with a statistically significant increase in odds of having an elevated CRP level in male participants (P<0.05, all models).

Our study findings revealed mixed results when examining the relationships between race and CRP in women. In comparison to a referent group of non-Hispanic white women, the odds of having an elevated CRP level for Mexican American women was significantly higher (P<0.001, all models). In comparison to female participants that do not report using hormone therapies, the odds of having an elevated CRP were significantly higher (P<0.0001, all models) for women using hormone therapies. Lastly, when examining WC measures in men and women the odds of having an elevated CRP level were significantly higher for every centimeter increment in WC [men (OR 1.04; CI 1.03–1.05, P<0.0001), women (OR 1.05; CI 1.04–1.06, P<0.0001)].

Discussion

Although some studies have shown that participation in various forms of MSA is associated with a decrease in CRP, the study populations were generally small and not representative of the U.S. population (13, 20, 32). For example, in a sample of 44 young male African American and white volunteers, six weeks of resistance training resulted in a significant decrease in CRP in African American subjects (Mean ± SE; Baseline CRP 4.84 ± 0.9 vs. Post Training CRP 2.34 ± 0.5mg/L, P<0.05) (20). Volunteers trained three days/week for approximately 60 minutes per session. Three sets of five different exercises per session were performed with a one to two minute rest period between each set. Load was progressively increased to ensure fatigue within approximately eight to12 repetitions. The study protocol utilized a split routine designed to alternate exercises for legs, back, and biceps on one day and exercises for the chest, shoulders, and triceps on a separate day. Thus, the selected exercises would effectively stress the major muscle groups of the upper and lower body. Interestingly, the observed decrease in CRP in these male African American volunteers remained statistically significant following a four week detraining period (CRP 1.91 ± 0.4mg/L).

Stewart et al. (32) examined the influence of a 12 week exercise protocol that utilized a combination of aerobic and resistance training on CRP concentrations in 29 younger (18–35 years of age) and 31 older (65–85 years of age) subjects. Participants trained three days/ week and each session included a warm-up, 20 minutes of aerobic training (walking/ jogging) on a treadmill (70–80% of heart rate reserve), and two sets of eight resistance exercises [70–80% one repetition maximum (1RM), second set performed to momentary failure] followed by a stretching and cool down period. Intensity was adjusted bi-weekly. These investigators reported a 58% decrease (P<0.01) in serum CRP concentrations from pre- to post-training in those classified as inactive prior to study participation.

Donges et al. (13) investigated the effects of 10 weeks of exercise training on interleukin-6 and CRP in a sample of 102 male (n=45) and female (n=57) sedentary subjects. Subjects were assigned to a resistance group (n=35), an aerobic group (n=41), or a control group (n=26) that remained sedentary. Training sessions began with five minutes of dynamic stretching and concluded with five minutes of stretching. The resistance training protocol utilized pulley-weight machines and exercises were performed at 10 repetition maximum (~75% of a 1RM). Resistance exercises included chest press, shoulder press, lat pull-down, seated row, leg press, leg curl, and lunge. Participants performed two to three sets of eight to10 repetitions with a two-minute rest period between sets. Intensity was adjusted accordingly to promote training to "momentary muscle failure". Aerobic training (~75% of maximum heart rate) was conducted using Monark stationary cycle ergometers. Interestingly, only resistance training resulted in a significant attenuation of CRP concentration, 32.8% ($P<0.05$).

Our findings support previous studies reporting adiposity as a mediating factor in the association between MSA and CRP levels in men and women (11, 12, 14, 24, 33, 34). In an analysis using baseline data from the Health, Aging and Body Composition Study, Colbert et al. (11) reported that CRP levels were significantly lower in older (aged 70–79 years) black and white adult study participants reporting higher levels of exercise (≥180 minutes/week) that included resistance training (e.g., weight training, calisthenics). However, the relationship between exercisers and non-exercisers was not statistically significant following adjustments for total body fat and visceral fat. Other studies have also noted the associations between body fat and elevated CRP concentrations (34), an association which has also been consistently shown to be stronger in women (12, 14, 24, 33).

When stratified by gender, previous studies analyzing the distribution of elevated CRP (>3 mg/L), or the relationship between PA and CRP, have produced mixed results (4, 7, 17, 21, 23, 25). In a study of older adults conducted by Canon et al. (7), analysis revealed that elevated levels of CRP mediated the relationship between cognitive function and muscle quality in females but not males. Albert et al. (4) reported that concentrations of CRP in participants of the Pravastatin Inflammation/CRP Evaluation study were statistically significantly lower among middle-aged men who self-reported a high level (≥4 times/week) of strenuous aerobic PA (e.g., swimming, running, aerobics, cycling). However, when compared with a referent group reporting participating in strenuous aerobic PA less than once/week, this relationship was not statistically significant in women (mean age in years, 60.8 ± 12 for both men and women). A study examining the association between fitness and CRP levels in children and young adult participants (n=205) in the Columbia University BioMarkers Study aged six to 24 years revealed statistically significant inverse associations only in male participants (21). Previous studies have also demonstrated independent associations between CRP and hand grip and lower body strength that appear to be stronger in women (19, 35).

In men, the 1999–2004 NHANES data revealed a statistically significant inverse association between having an elevated CRP concentration and meeting the current DHHS recommendations. In women, a statistically significant inverse association was revealed in those reporting any level of MSA participation. These associations were independent of,

race, increased levels of non-HDL-C, and hormone therapies in women and reduced HDL-C levels, increased levels of non-HDL-C, increased HbA1c, hypertension, and increased serum cotinine concentrations in men. However, adjustment for WC attenuated the protective association between reporting MSA and having elevated CRP in men and resulted in an absence of statistically significant associations in women for any volume of MSA. Since CRP has shown efficacy in predicting risk of incident CVD (30), these findings may be particularly important for men and women who do not currently perform any volume of MSA, or for men performing volumes of MSA that do not meet the recommendation.

The observed associations between CRP and MSA were also consistent with other studies which have demonstrated more pronounced associations among non-Caucasian female subgroups (23, 25) and those reporting adiposity as a strong mediating factor (17, 33, 34). Consequently, because MSA participation has been estimated to be lower in female subgroups (8), it may become increasingly important for health care professionals to promote MSA participation in these groups.

Our study included some inherent strengths and limitations. To the best of our knowledge, this is one of the first studies to examine the association between MSA and CRP in a gender-stratified analysis using surveillance data. Additionally, the NHANES sample is large and representative of the U.S adult population, thus strengthening the external validity of our study. Several limitations also warrant consideration. The MSA variable was created from a series of questions in which participant responses may have been influenced by social desirability, and due to the nature of the cross-sectional study design, causality cannot be inferred.

Conclusions

Our population-based findings add to the current evidence suggesting that MSA is associated with lower levels of CRP. Women reporting any MSA were found to have statistically significantly lower odds of having elevated CRP when compared to those reporting no MSA. However, significantly lower odds in men were only observed in those meeting the DHHS recommendation. These results also suggest that adiposity may mediate the associations between MSA and CRP. Future studies should examine the associations among MSA, CRP, and other markers of metabolic health.

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References

1. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). JAMA. 2001; 285(19):2486–2497. [PubMed: 11368702]
2. Physical activity guidelines for Americans; Be active, healthy, and happy. U.S. Department of Health and Human Services; 2008. Available from
3. Ablij H, Meinders A. C-reactive protein: history and revival. Eur J Intern Med. 2002; 13(7):412. [PubMed: 12384129]

4. Albert MA, Glynn RJ, Ridker PM. Effect of physical activity on serum C-reactive protein. Am J Cardiol. 2004; 93(2):221–225. [PubMed: 14715354]
5. American Diabetes A. Diagnosis and classification of diabetes mellitus. Diabetes care. 2010; 33(Supplement 1):S62–S69. [PubMed: 20042775]
6. Benowitz NL, Bernert JT, Caraballo RS, Holiday DB, Wang J. Optimal serum cotinine levels for distinguishing cigarette smokers and nonsmokers within different racial/ethnic groups in the United States between 1999 and 2004. Am J Epidemiol. 2009; 169(2):236–248. [PubMed: 19019851]
7. Canon ME, Crimmins EM. Sex differences in the association between muscle quality, inflammatory markers, and cognitive decline. J Nutr Health Aging. 2011; 15(8):695–698. [PubMed: 21968867]
8. Carlson SA, Fulton JE, Schoenborn CA, Loustalot F. Trend and prevalence estimates based on the 2008 Physical Activity Guidelines for Americans. Am J Prev Med. 2010; 39(4):305–313. [PubMed: 20837280]
9. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrtion Examination Survey Analytic and Reporting Guidelines. Hyattsville (MD): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2006. Available from: http://www.cdc.gov/nchs/data/nhanes/nhanes_03_04/nhanes_analytic_guidelines_dec_2005.pdf
10. Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Examination Protocol. Hyattsville (MD): U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2004. Available from: http://www.cdc.gov/nchs/nhanes/about_nhanes.htm
11. 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]
12. Connelly PW, Hanley AJ, Harris SB, Hegele RA, Zinman B. Relation of waist circumference and glycemic status to C-reactive protein in the Sandy Lake Oji-Cree. Int J Obes Relat Metab Disord. 2003; 27(3):347–354. [PubMed: 12629562]
13. Donges CE, Duffield R, Drinkwater EJ. Effects of resistance or aerobic exercise training on interleukin-6, C-reactive protein, and body composition. Med Sci Sports Exerc. 2010; 42(2):304–313. [PubMed: 20083961]
14. Festa A, D'Agostino R Jr, Williams K, Karter AJ, Mayer-Davis EJ, Tracy RP, Haffner SM. The relation of body fat mass and distribution to markers of chronic inflammation. Int J Obes Relat Metab Disord. 2001; 25(10):1407–1415. [PubMed: 11673759]
15. Ford ES, Giles WH. Serum C-reactive protein and fibrinogen concentrations and self-reported angina pectoris and myocardial infarction: findings from National Health and Nutrition Examination Survey III. J Clin Epidemiol. 2000; 53(1):95–102. [PubMed: 10693909]
16. Ford ES, Giles WH. Serum C-reactive protein and self-reported stroke: findings from the Third National Health and Nutrition Examination Survey. Arterioscler Thromb Vasc Biol. 2000; 20(4): 1052–1056. [PubMed: 10764672]
17. 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):242–250. [PubMed: 11157411]
18. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation. 2005; 112(17):2735–2752. [PubMed: 16157765]
19. Hamer M, Molloy GJ. Association of C-reactive protein and muscle strength in the English Longitudinal Study of Ageing. Age Dordr. 2009; 31(3):171–177. [PubMed: 19466582]
20. Heffernan KS, Jae SY, Vieira VJ, Iwamoto GA, Wilund KR, Woods JA, Fernhall B. C-reactive protein and cardiac vagal activity following resistance exercise training in young African-American and white men. Am J Physiol Regul Integr Comp Physiol. 2009; 296(4):R1098–1105. [PubMed: 19193941]
21. Isasi CR, Deckelbaum RJ, Tracy RP, Starc TJ, Berglund L, Shea S. Physical fitness and C-reactive protein level in children and young adults: the Columbia University BioMarkers Study. Pediatrics. 2003; 111(2):332–338. [PubMed: 12563060]

22. 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):1563–1569. [PubMed: 15893167]
23. Khera A, McGuire DK, Murphy SA, et al. Race and gender differences in C-reactive protein levels. J Am Coll Cardiol. 2005; 46(3):464–469. [PubMed: 16053959]
24. Lear SA, Chen MM, Birmingham CL, Frohlich JJ. The relationship between simple anthropometric indices and C-reactive protein: ethnic and gender differences. Metabolism. 2003; 52(12):1542–1546. [PubMed: 14669152]
25. Majka DS, Chang RW, Vu TH, et al. Physical activity and high-sensitivity C-reactive protein: the multi-ethnic study of atherosclerosis. Am J Prev Med. 2009; 36(1):56–62. [PubMed: 19013748]
26. Mora S, Cook N, Buring JE, Ridker PM, Lee IM. Physical activity and reduced risk of cardiovascular events: potential mediating mechanisms. Circulation. 2007; 116(19):2110–2118. [PubMed: 17967770]
27. Nocon M, Hiemann T, Muller-Riemenschneider F, Thalau F, Roll S, Willich SN. Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. Eur J Cardiovasc Prev Rehabil. 2008; 15(3):239–246. [PubMed: 18525377]
28. Pearson TA, Mensah GA, Alexander RW, et al. Markers of inflammation and cardiovascular disease: application to clinical and public health practice: A statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. Circulation. 2003; 107(3):499–511. [PubMed: 12551878]
29. Research Triangle Institute. SUDAAN User's Manual, Release 8.0. Durham (NC): 2001.
30. Ridker PM. Clinical application of C-reactive protein for cardiovascular disease detection and prevention. Circulation. 2003; 107(3):363–369. [PubMed: 12551853]
31. Statistical Analysis System (SAS) Institute Inc. Base SAS 9.2 Procedures Guide. Cary (NC): 2009.
32. Stewart LK, Flynn MG, Campbell WW, et al. The influence of exercise training on inflammatory cytokines and C-reactive protein. Med Sci Sports Exerc. 2007; 39(10):1714–1719. [PubMed: 17909397]
33. Thorand B, Baumert J, Doring A, et al. Sex differences in the relation of body composition to markers of inflammation. Atherosclerosis. 2006; 184(1):216–224. [PubMed: 15993885]
34. Visser M, Bouter LM, McQuillan GM, Wener MH, Harris TB. Elevated C-reactive protein levels in overweight and obese adults. JAMA. 1999; 282(22):2131–2135. [PubMed: 10591334]
35. Visser M, Pahor M, Taaffe DR, et al. Relationship of interleukin-6 and tumor necrosis factor-alpha with muscle mass and muscle strength in elderly men and women: the Health ABC Study. J Gerontol A Biol Sci Med Sci. 2002; 57(5):M326–332. [PubMed: 11983728]
36. 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):1785–1790. [PubMed: 11956120]

Table 1

Prevalence of Elevated CRP According to Sample Characteristics: NHANES 1999–2004

Covariates	Men		Women	
	N	***Weighted % (SE %)***	***N***	***Weighted % (SE %)***
Total	4072	24.4 (0.93)	3464	36.0 (0.91)
MSA				
None	2977	26.7 (1.08)	2756	38.5 (1.14)
Some Activity	248	20.4 (3.15)	172	25.5 (2.62)
Meets Rec.	847	19.8 (1.30)	536	30.3 (2.15)
Age				
20–39	1265	18.9 (1.31)	1025	30.3 (1.60)
40–59	1302	25.8 (1.43)	1070	38.4 (1.61)
≥ 60	1505	31.4 (1.51)	1369	42.0 (1.83)
Race				
nH White	2140	23.8 (1.14)	1790	35.3 (1.15)
nH Black	687	27.7 (1.69)	597	38.6 (2.31)
Mexican American	962	23.8 (1.21)	801	44.3 (1.60)
Other	283	26.1 (2.51)	276	34.6 (2.92)
Education				
< High School	1372	29.1 (1.65)	1096	39.7 (2.28)
High School Graduate	937	25.1 (1.55)	850	36.8 (1.78)
> High School	1763	22.4 (1.17)	1518	35.0 (1.55)
Cotinine (ng/mL)				
< 3	2798	22.6 (1.17)	2754	35.8 (1.03)
≥ 3	1274	28.3 (1.49)	710	36.6 (1.83)
Low HDL-C (mg/dL)				
No	2551	20.7 (1.04)	1965	31.6 (1.11)
Yes	1521	30.6 (1.61)	1499	42.9 (1.46)
Non-HDL-C (mg/dL)				
< 130	1370	20.2 (1.34)	1361	28.6 (1.36)
130 to < 160	1113	22.6 (1.12)	926	37.4 (1.57)
160 to < 190	886	27.3 (2.05)	670	41.4 (2.40)
≥ 190	703	31.5 (2.33)	507	52.3 (2.87)
Glycohemoglobin (%)				
< 5.7	2957	21.8 (0.88)	2585	33.5 (1.05)
5.7 to < 6.5	707	38.0 (3.58)	590	57.9 (4.18)
≥ 6.5	408	41.1 (5.38)	289	53.0 (7.40)
Hypertension				
SBP < 140 and DBP < 90	2582	22.1 (1.22)	2120	33.3 (1.03)
SBP ≥ 140, or DBP ≥ 90	1490	32.5 (1.99)	1344	43.1 (3.15)
Augmented WC				

Covariates	Men		Women	
	N	***Weighted % (SE %)***	***N***	***Weighted % (SE %)***
No	2437	17.1 (1.02)	1367	20.8 (1.22)
Yes	1635	36.4 (1.95)	2097	50.4 (1.23)
Hormone Therapy				
No			2473	33.8 (1.16)
Yes			991	41.8 (3.82)

Independent variables included muscle strengthening activity (MSA), age (years), race, education, serum cotinine, low high-density lipoprotein cholesterol (HDL-C) Men (<40 mg/dL) Women (<50 mg/dL), non-high-density lipoprotein cholesterol (non-HDL-C), Glycohemoglobin (%), hypertension, augmented waist circumference (WC) Men (yes: ≥102 cm, no: <102 cm), Women (yes: ≥88 cm, no <88 cm), and hormone therapy.

Abbreviations: Elevated CRP, elevated C - reactive protein (>3 mg/L to ≤10 mg/L); SE, standard error; nh, non-Hispanic; SBP, systolic blood pressure; DBP, diastolic blood pressure; ng/mL, nanogram per milliliter; mg/dL, milligram per deciliter

Table 2

Odds Ratios for Muscle Strengthening Activity as a Predictor of Elevated CRP for Men in a Sample from the National Health and Nutrition Examination Survey Cycles 1999–2004

Variable	*Model 1 OR (95% CI)*	*Model 2 OR (95% CI)*	*Model 3 OR (95% CI)*
MSA			
None	1.00	1.00	1.00
Some Activity	0.65 (0.46–0.92) *	0.80 (0.55–1.17)	0.90 (0.61–1.34)
Meets Rec.	0.57 (0.49–0.67) *	0.73 (0.61–0.88) *	0.77 (0.63–0.95) *
Non-HDL-C (mg/dL)			
< 130		1.00	1.00
130 to < 160		1.20 (0.96–1.50)	1.11 (0.88–1.41)
160 to < 190		1.59 (1.19–2.12) *	1.43 (1.07–1.91) *
≥ 190		1.78 (1.36–2.31) *	1.56 (1.19–2.04) *
HDL-C (mg/dL)			
≥ 40		1.00	1.00
< 40		1.50 (1.25–1.81) *	1.24 (1.02–1.51) *
Cotinine (ng/mL)			
< 3		1.00	1.00
≥ 3		1.31 (1.09–1.59) *	1.55 (1.25–1.94) *
Glycohemoglobin (%)			
< 5.7		1.00	1.00
5.7 to < 6.5		1.79 (1.48–2.16) *	1.43 (1.14–1.78) *
≥ 6.5		1.84 (1.27–2.66) *	1.35 (0.94–1.93)
Hypertension			
SBP ≤ 140, or DBP ≤ 90		1.00	1.00
SBP > 140, or DBP > 90		1.67 (1.32–2.12) *	1.32 (1.02–1.71) *
WC (cm)			
			1.04 (1.03–1.05) *

Independent variable(s) included in Model 1: muscle strengthening activity; Model 2: muscle strengthening activity, non-high density lipoprotein cholesterol, high density lipoprotein cholesterol, Serum Cotinine, Glycohemoglobin, and hypertension; Model 3 included all variables from Model 2 and waist circumference.

* Significant predictors (P<0.05).

Abbreviations: OR, odds ratio; CI, confidence interval; MSA, muscle strengthening activity; HDL-C, high density lipoprotein cholesterol; WC, waist circumference; BP, blood pressure; SBP, systolic blood pressure; DBP; diastolic blood pressure; cm, centimeter; mg/dL, milligram per deciliter; ng/mL, nanogram per milliliter

Table 3

Odds Ratios for Muscle Strengthening Activity as a Predictor of Elevated CRP for Women in a Sample from the National Health and Nutrition Examination Survey Cycles 1999–2004

Variable	*Model 1 OR (95% CI)*	*Model 2 OR (95% CI)*	*Model 3 OR (95% CI)*
MSA			
None	1.00	1.00	1.00
Some Activity	0.49 (0.36–0.67) *	0.61 (0.45–0.83) *	0.79 (0.56–1.12)
Meets Rec.	0.62 (0.51–0.75) *	0.66 (0.54–0.82) *	0.93 (0.73–1.17)
Non-HDL-C (mg/dL)			
< 130		1.00	1.00
130 to < 160		1.48 (1.25–1.75) *	1.43 (1.18–1.73) *
160 to < 190		1.77 (1.40–2.24) *	1.53 (1.19–1.96) *
≥ 190		2.69 (2.12–3.43) *	2.16 (1.70–2.73) *
Race			
nH White		1.00	1.00
nH Black		1.23 (1.02–1.49) *	0.97 (0.80–1.17)
Mexican American		1.55 (1.25–1.92) *	1.50 (1.25–1.80) *
Other		0.92 (0.72–1.17)	1.05 (0.78–1.40)
Hormone Therapy			
No		1.00	1.00
Yes		1.60 (1.35–1.90) *	1.51 (1.26–1.81) *
WC (cm)			
			1.05 (1.04–1.06) *

Independent variable(s) included in Model 1: muscle strengthening activity; Model 2: muscle strengthening activity, non-high density lipoprotein cholesterol, race, and hormone therapy; Model 3 included all variables from Model 2 and waist circumference.

* Significant predictors ($P<0.05$).

Abbreviations: OR, odds ratio; CI, confidence interval; MSA, muscle strengthening activity; HDL-C, high density lipoprotein cholesterol; nH, non-Hispanic; WC, waist circumference; cm, centimeter; mg/dL, milligram per deciliter