J Chron Dis Vol. 39, No. 2, pp. 115–120, 1986
Printed in Great Britain. 

0021-9681/86 $3.00 + 0.00


# VIGOROUS PHYSICAL ACTIVITY AND CARDIOVASCULAR RISK FACTORS IN YOUNG ADULTS

JAMES F. SALLIS, WILLIAM L. HASKELL, PETER D. WOOD, STEPHEN P. FORTMANN and KAREN M. VRANIZAN

Stanford Center for Research in Disease Prevention and University of California, San Diego, La Jolla, CA 92093, U.S.A.

(*Received* 19 *June* 1985)

**Abstract**—There are conflicting data regarding the effects of vigorous physical activity (PA) and cardiovascular disease risk factors. Representative samples of adults aged 20–35 from four northern California cities were studied both cross-sectionally and longitudinally in order to examine the relationships between vigorous PA and selected physiological risk factors. A self-report measure of habitual vigorous PA was validated by pulse rate. There were relationships, in both cross-sectional and longitudinal analyses between self-reported vigorous PA and HDL/LDL ratio, especially for women. Relationships in cross-sectional analyses only were found between PA and diastolic blood pressure, total cholesterol, HDL-cholesterol, triglycerides, and alveolar carbon monoxide. The results of the present study generally tend to confirm investigations of other samples.

## INTRODUCTION

REGULAR participation in vigorous activity (i.e. at least 7.5 kcal/min) has been found to be protective against fatal and nonfatal cardiovascular disease [1–3]. The mechanism of this protective effect has not been elucidated, but one hypothesis is that physical activity may beneficially affect other established cardiovascular disease (CVD) risk factors, such as serum lipoproteins, obesity, blood pressure, or cigarette smoking. However, epidemiologic studies offer conflicting data on the relationship between physical activity and these risk factors.

In order to clarify the inconsistent findings of previous studies, this paper presents the results of both cross-sectional and longitudinal analyses of the relationship between vigorous exercise and CVD risk factors in a representative sample of California men and women aged 20–35.

## METHODS

### *Subjects*

As part of the Stanford Community Health Survey representative samples of residents of Monterey, Salinas, Modesto, and San Luis Obispo, California, completed comprehensive health surveys. Approximately 500 households were randomly chosen from a commercial directory for each community. A sample of 2119 men and woman between the ages of 20 and 74 were interviewed at the *baseline* assessment (May 1979–April 1980), and the acceptance rate was 66.4%. One year later, 1411 (66.6%) returned for a follow-up

Address correspondence to: James F. Sallis, Ph.D., Division of General Pediatrics, M-020-F, University of California, San Diego, La Jolla, CA 92093, U.S.A.

interview (May 1980–April 1981). However, of those interviewed at baseline, 424 moved away and 11 died, yielding an adjusted response rate of 83.8%. Both interviews were conducted in approximately the same month to avoid the confounding of seasonal variation. A second independent sample (May 1981–April 1982) of all four cities achieved a response rate of 75.3%. There were 1946 adult participants in the second survey. Response rates for the 20–35 age group were slightly higher than those detailed here.

For the analysis presented below, two samples of adults aged 20–35 were constructed. Analyses were restricted to subjects in this age range because very few people in older age groups reported participating in vigorous activities [4]. The cross-sectional sample consisted of men and women who were interviewed at either the baseline or the second independent sample survey. There were 809 women and 953 men in this cross-sectional sample. The second, longitudinal, sample consisted of 20–35 year old subjects who participated in both the baseline and follow-up surveys. There were 281 women and 250 men in the longitudinal sample.

*Assessment*

The health survey required approximately 2 hours and was carried out by trained staff who were periodically monitored for quality control. The variables used in the present studies are described below.

*Vigorous physical activity.* Subjects were asked in a personal interview whether they had regularly engaged in specific activities at a criterion level, for at least the past 3 months. These criterion levels were chosen based on estimated caloric requirements to reflect the frequency and duration of activity needed to produce a cardiovascular training effect [5]. The activities and their criterion levels are as follows: (a) jog or run at least ten miles per week, (b) play strenuous racquet sports (singles tennis, paddle ball, etc.) at least five hours per week, (c) play other strenuous sports (basketball, soccer, etc.) at least five hours per week, (d) ride a bicycle at least 50 miles per week or (e) swim at least two miles per week. The reliability of this scale is 0.83 [4]. Thus, subjects who endorsed any item were presumed to be engaging in substantial amounts of vigorous physical activity.

Subjects in the longitudinal sample were categorized according to their reported change in vigorous activity between baseline and follow-up. Figure 1 is a diagram of the classification process which includes the number of men and women in each category. Subjects were first classified as to whether they reported none ("inactive") or at least one ("active") vigorous activity at baseline. Those reporting no vigorous activity at baseline were termed "sedentary" if they continued to report no activity 1 year later at follow-up or "adopter" if they reported regular participation in vigorous activity at follow-up. Subjects claiming to be vigorously active at baseline were classified "maintainer" if they reported vigorous activity at follow-up or "quitter" if they reported no regular vigorous activity at follow-up.

*Risk factors.* Blood pressure (systolic and fifth phase diastolic) was obtained on participants sitting at rest for 2 min. Pressures were obtained twice using a standard mercury sphygmomanometer. Pulse rate was measured before blood pressure readings for

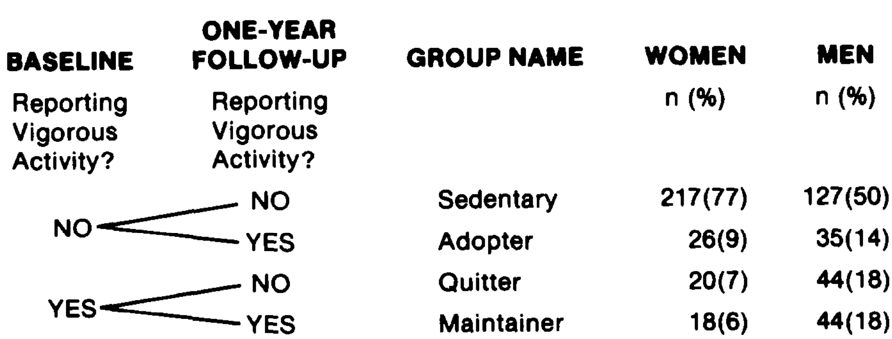


FIG. 1. Classification of subjects in the longitudinal sample.

30 sec. Non-fasting blood samples were analyzed for total plasma cholesterol and the cholesterol content of the high density (HDL) and low density (LDL) lipoprotein subfractions and plasma triglycerides, using Lipid Research Clinics Program procedures [6]. Height and weight were measured with clothes but not shoes or overgarments. Body mass index (BMI: $kg/m^2$) was used as a measure of obesity [7]. Alveolar carbon monoxide was measured by an Ecolyzer (Bioenergetics Corp. Elsmford, New York) and was used as a physiological index of smoking [8].

All analyses were conducted using the Statistical Analysis System package [9].

## RESULTS

*Cross-sectional analyses*

Fifteen percent of the 809 women and 38% of the 953 men reported vigorous activity. Analyses of covariance were used to compare the active and inactive groups for each risk factor. Years of education was used as the covariate because education was associated with vigorous activity and risk factors. These results are summarized in Table 1. Diastolic BP was lower in active women, but systolic BP did not differ between active and inactive young adults. There was a significant difference in total plasma cholesterol between men who did and did not report regular vigorous activity. Women exercisers had higher HDL-cholesterol and vigorously active women and men had higher HDL/LDL ratios. Plasma triglyceride level was lower in very active men. Pulse rate was much lower in both men and women exercisers, but there were no significant differences between vigorously active and sedentary groups in BMI. Expired carbon monoxide was lower in active women.

*Longitudinal analyses*

Analyses of variance were conducted on change scores for each risk factor across exercise groups (i.e. sedentary, adopter, quitter, maintainer). These analyses were followed by contrasts between sedentary and adopter groups and between quitter and maintainer groups. Because two contrasts were made for each overall analysis of variance, an adjusted level of significance of $p < 0.025$ was used [10]. The results of these analyses are presented in Table 2.

Whereas most of the group mean change scores were in the predicted direction, few differences were statistically significant. For women, adopters had a greater increase in HDL/LDL ratio than the sedentary group, and adopters showed a significant decrease in pulse rate. Men who dropped out of vigorous activity (quitters) increased their pulse rate,

TABLE 1. RELATIONSHIP OF VIGOROUS ACTIVITY TO RISK FACTORS FOR MEN AND WOMEN, AGE 20–35

| Risk factor | | No vigorous activity | Vigorous activity | *F* | *p* |
|---|---|---|---|---|---|
| Pulse rate (bpm) | women | 72.0* | 67.6 | 17.65 | 0.0001 |
| | men | 69.0 | 65.6 | 23.97 | 0.0001 |
| Triglycerides | women | 94.4 | 89.9 | 0.81 | 0.37 |
| | men | 140.3 | 127.0 | 4.00 | 0.05 |
| Systolic BP (mmHg) | women | 109.4 | 107.5 | 2.42 | 0.12 |
| | men | 122.2 | 122.1 | 0.02 | 0.89 |
| Diastolic BP (mmHg) | women | 69.2 | 67.1 | 3.96 | 0.05 |
| | men | 75.1 | 74.7 | 0.33 | 0.57 |
| Cholesterol (mg/dl) | women | 173.7 | 172.0 | 0.27 | 0.60 |
| | men | 180.1 | 174.9 | 4.77 | 0.03 |
| LDL-C (mg/dl) | women | 98.0 | 93.5 | 2.25 | 0.11 |
| | men | 105.7 | 101.3 | 2.09 | 0.13 |
| HDL-C (mg/dl) | women | 56.8 | 60.5 | 7.48 | 0.006 |
| | men | 47.5 | 48.7 | 2.21 | 0.14 |
| HDL/LDL | women | 0.63 | 0.69 | 4.99 | 0.03 |
| | men | 0.495 | 0.55 | 10.05 | 0.002 |
| BMI ($kg/m^2$) | women | 0.233 | 0.228 | 1.37 | 0.24 |
| | men | 0.248 | 0.246 | 0.77 | 0.38 |
| Carbon monoxide (ppm) | women | 10.7 | 6.1 | 5.55 | 0.02 |
| | men | 11.4 | 10.1 | 1.26 | 0.26 |
| *N* | women | 689 | 120 | | |
| | men | 593 | 360 | | |

*Education-adjusted means.

TABLE 2. CHANGE IN RISK FACTORS IN RELATION TO CHANGE IN VIGOROUS ACTIVITY OVER ONE YEAR IN MEN AND WOMEN, AGE 20–35 YEARS

| Risk | | ANOVA *F* | *P* | Sedentary vs. | Adopters | *P* | Quitters vs. | Maintainers | *P* |
|---|---|---|---|---|---|---|---|---|---|
| Pulse rate (bpm) | women | 1.86 | 0.13 | 1.38* | −3.11 | | 0.60 | 3.80 | |
| | men | 3.38 | 0.02 | 1.12 | −0.22 | 0.51 | 6.26 | 0.33 | 0.009 |
| Triglycerides | women | 1.25 | 0.29 | −2.30 | −7.41 | | −18.40 | −24.00 | |
| | men | 1.80 | 0.15 | 24.36 | 58.78 | | 24.83 | 4.80 | |
| Systolic BP (mmHg) | women | 0.46 | 0.71 | −1.34 | −0.52 | | −2.60 | −3.70 | |
| | men | 0.65 | 0.59 | −3.58 | −2.38 | | −1.19 | −3.63 | |
| Cholesterol (mg/dl) | women | 1.13 | 0.34 | −1.72 | −6.77 | | −11.45 | 1.16 | |
| | men | 1.24 | 0.30 | −3.74 | −2.00 | | −3.89 | 3.57 | |
| Diastolic BP (mmHg) | women | 0.80 | 0.50 | −1.17 | −0.59 | | −1.90 | −1.90 | |
| | men | 1.54 | 0.20 | −1.32 | 0.81 | | −2.55 | −3.84 | |
| LDL-C (mg/dl) | women | 1.23 | 0.30 | −3.80 | −8.31 | | −10.25 | 1.21 | |
| | men | 1.85 | 0.14 | 3.91 | −4.39 | | −5.53 | 1.63 | |
| HDL-C (mg/dl) | women | 2.49 | 0.06 | −1.60 | 1.54 | | −7.25 | 0.16 | |
| | men | 1.57 | 0.20 | −2.83 | −1.67 | | −2.77 | 0.37 | |
| HDL/LDL | women | 3.93 | 0.009 | 0.002 | 0.15 | 0.001 | 0.01 | 0.07 | 0.40 |
| | men | 0.44 | 0.73 | −0.03 | −0.0009 | | −0.02 | −0.008 | |
| BMI (kg/m$^2$) | women | 0.64 | 0.59 | 0.0027 | −0.0014 | | −0.0023 | 0.0036 | |
| | men | 1.15 | 0.33 | 0.0026 | 0.0019 | | 0.0038 | −0.0005 | |
| Carbon Monoxide (ppm) | women | 0.79 | 0.50 | 0.31 | 0.59 | | 2.81 | 0.40 | |
| | men | 1.04 | 0.38 | −0.20 | −2.06 | | −2.18 | −0.55 | |
| *N* | women | | | 217 | 26 | | 20 | 18 | |
| | men | | | 127 | 35 | | 44 | 44 | |

*Mean change score (post–pre).

and this was the only significant difference in risk factors between exercise change groups for men.

## DISCUSSION

The relationship between vigorous physical activity and CVD risk factors is an unsettled issue because of conflicting data. The Stanford Community Health Survey provides an opportunity to examine this issue with both longitudinal and cross-sectional data. Thus, relationships found in both samples would be strongly supported and relationships found in only one sample would be weakly supported. In interpreting the results of these analyses, it should be considered that the subjects present a slightly more healthy risk factor profile than found in the Lipid Research Clinics Prevalence Study [11] and that subject sampling and follow-up were incomplete.

Two effects of physical activity that have been consistently documented are decreases in resting pulse rate [12, 13] and serum triglycerides [14, 15]. In the present study lower pulse rates were found in active men and women in the cross-sectional sample, and this was confirmed in the longitudinal sample. Thus, the vigorous activity self-report measure was found to have some validity and to be capable of detecting change. Differences in serum triglycerides may have been obscured because of nonfasting samples.

The weak associations between activity and BP that have been reported in other epidemiologic studies [1, 3, 16–19] were mirrored in the present study. The finding that only vigorously active women had lower diastolic BP replicated the Salonen *et al.* [3] results. Lack of effect of vigorous activity on BP is difficult to reconcile with various training studies [20–22] and at least one epidemiologic study [18], but may be partly explained by the lack of weight change in the present cohort.

Inconsistent associations between activity and total cholesterol have been found previously [1, 3, 14–16, 19, 23, 24] as well as in the present study. The relationship with HDL-cholesterol was weakly documented, but the relationship between vigorous activity and the HDL/LDL ratio was strongly supported in the present study. The HDL/LDL ratio was related to vigorous activity cross-sectionally for both men and women, and this was confirmed longitudinally for women.

No differences in BMI were found between activity groups in the cross-sectional or longitudinal samples. Thus, this study does not support previous findings that vigorous activity is associated with loss of body mass [12, 19, 20, 23–26]. While exercise has often been associated with decreased percentage body fat [12, 13, 23, 26, 27], exercise-induced increases in lean body weight [27] could result in no detectable change in BMI. Thus, measures of body composition are needed to further examine the relationship between activity and adiposity.

While some studies have suggested that vigorously active people smoke less [17, 19, 20], this finding received only weak support in the present investigation. There was no trend for changes in activity to be related to changes in carbon monoxide level and this result is consistent with the bulk of the evidence [1, 16, 21, 25, 28–30].

Relationships between vigorous activity and risk factors are strongly supported when found in both cross-sectional and longitudinal analyses. However, inconsistencies between the two types of analyses could be the result of many factors. For example, decreased sample size in the longitudinal study makes differences between groups difficult to detect. Differences between those who participated in both assessments and subjects who did not complete the second evaluation could affect the findings in unknown ways. Additionally, the extent of exercise participation occurring between the two assessments of the longitudinal sample could vary from 3 to 12 months. This variable exercise dose could make it difficult to adequately estimate physiological responses. Thus, cross-sectional findings should not be discounted only because they were not confirmed in longitudinal analyses.

In summary, the self-report of vigorous activity was partially validated by the strong relationship with resting pulse rate. The only risk factor relationship for which strong support was found was the HDL/LDL ratio, and the evidence was stronger for women. Weak support of relationships between vigorous activity and HDL-cholesterol and diastolic BP for women, and total cholesterol and triglycerides for men were found. A weak association between activity and alveolar carbon monoxide was found. The results of the present study are in general agreement with previous findings that vigorous physical activity is related to HDL-cholesterol [14, 15], but unrelated to most health behaviors [31]. However, present findings are inconsistent with reports that physical activity is associated with weight control [31].

*Acknowledgements*—This work was supported by NIH grant HL 21906 and Dr. Sallis was partially supported by NIH training grant HL 07034. The assistance of Andrea Cody is greatly appreciated for manuscript preparation.

## REFERENCES

1. Dawber TR: **The Framingham Study: The Epidemiology of Atherosclerotic Disease.** Cambridge, MA: Harvard, 1980
2. Paffenbarger RS, Wing AL, Hyde RT: Physical activity as an index of heart attack risk in college alumni. **Am J Epid** 108: 161–175, 1978
3. Salonen JT, Puska P, Tuomilehto J: Physical activity and risk of myocardial infarction, cerebral stroke, and death: A longitudinal study in Eastern Finland. **Am J Epid** 115: 526–537, 1982
4. Sallis JF, Haskell WL, Wood PD, Fortmann SP, Rogers T, Blair SN, Paffenbarger RS: Physical activity assessment methodology in the Five-City Project. **Am J Epid** 121: 91–106, 1985
5. American College of Sports Medicine. **Guidelines for Graded Exercise Testing and Exercise Prescription,** 2nd edn. Philadelphia: Lea & Febiger, 1980
6. U.S. Department of Health, Education, and Welfare: **Lipid Research Clinics Manual of Laboratory Operations.** Vol. 1. Lipid and Lipoprotein Analysis. Washington, D.C.: DHEW (Pub. no [NIH] 75–628), 1974
7. Thomas AE, McKay DA, Cutlip MB: A monograph method for assessing body weight. **Am J Clin Nutr** 29: 302–304, 1976
8. Frederiksen LW, Martin JE: Carbon monoxide and smoking behavior. **Addict Behav** 4: 21–30, 1979
9. SAS Institute: **Statistical Analysis System User's Guide.** Cary, NC: SAS Institute, Inc., 1979
10. Dunn OJ: Multiple comparisons among means. **J Am Stat Assoc** 56: 52–64, 1961
11. U.S. Department of Health and Human Services: **The Lipid Research Clinics Population Studies Data Book.** Vol. I. The Prevalence Study. Washington, D.C.: DHHS (Pub. No. [NIH] 80–1527), 1980
12. Hartung GH, Farge EJ, Mitchell RE: Effects of marathon running, jogging, and diet on coronary risk factors in middle-aged men. **Prev Med** 10: 316–323, 1981
13. Upton SJ, Hagan RD, Rosentsweig J, Gettman LR: Comparisons of the physiological profiles of middle-aged women distance runners and sedentary women. **Res Q Exer Sport** 54: 83–87, 1983
14. Wood PD, Haskell WL: The effect of exercise on plasma high density lipoproteins. **Lipids** 14: 417–427, 1979
15. Haskell WL: Exercise-induced changes in plasma lipids and lipoproteins. **Prev Med** 13: 23–36, 1984

16. Epstein L, Miller GJ, Stitt FW, Morris JN: Vigorous exercise in leisure time, coronary risk factors, and resting electrocardiogram in middle-aged male civil servants. **Br Heart J** 38: 403–409, 1976
17. Holme I, Helgeland A, Hjermann I, Leren P, Lund-Larsen PG: Physical activity at work and leisure in relation to coronary risk factors and social class. **Acta Med Scand** 209: 277–283, 1981
18. Paffenbarger RS, Wing AL, Hyde RT, Jung DL: Physical activity and incidence of hypertension in college alumni. **Am J Epid** 117: 245–257, 1983
19. Folsom AR, Casperson CJ, Taylor HL, Jacobs DR, Luepker RV, Gomez-Marin O, Gillum RF, Blackburn H: Leisure time physical activity and its relationship to coronary risk factors in a population-based sample. **Am J Epid** 121: 570–579, 1985
20. Mann GV, Garrett HL, Farhi A, Murray H, Billings FT: Exercise to prevent coronary heart disease: An experimental study of the effects of training on risk factors for coronary disease in men. **Am J Med** 46: 12–27, 1969
21. Bonanno JA, Lies JE: Effects of physical training on coronary risk factors. **Am J Cardiol** 33: 760–764, 1974
22. Roman O, Camuzzi AL, Villalon E, Klenner C: Physical training program in arterial hypertension: A long term prospective follow-up. **Cardiol** 67: 230–243, 1981
23. Montoye HJ, Block WD, Metzner HL, Keller JB: Habitual physical activity and serum lipids: Males, age 16–64 in a total community. **J Chron Dis** 29: 697–709, 1976
24. Costas P, Garcia-Palmieri MR, Nazario E, Sorlie P: Relation of lipids, weight, and physical activity to incidence of coronary heart disease: The Puerto-Rico Heart Study. **Am J Cardiol** 42: 653–658, 1978
25. Wood PD, Haskell WL, Blair SN, Williams PT, Krauss RM, Lindgren FT, Albers JJ, Ho PH, Farquhar JW: Increased exercise level and plasma lipoprotein concentrations: A one-year randomized, controlled study in sedentary, middle-aged men. **Metabolism** 32: 31–39, 1983
26. Rauramaa R, Salonen JT, Kukkonen-Harjula K, Seppanen K, Seppala E, Vapaatalo H, Huttunen JK: Effects of mild physical exercise on serum lipoproteins and metabolites of arachidonic acid: A controlled randomised trial in middle aged men. **Br Med J** 288: 603–606, 1984
27. Wilmore JH, Davis JA, O'Brien RS, Vodak PA, Walter GR, Amsterdam EA: Physiological alterations consequent to 20-week conditioning programs of bicycling, tennis, and jogging. **Med Sci Sport Exer** 12: 1–8, 1980
28. Frank CW, Weinblatt E, Shapiro S, Sager RV: Myocardial infarction in men: Role of physical activity and smoking in incidence and mortality. **JAMA** 198: 103–107, 1966
29. Ilmarinen J, Fardy PS: Physical activity intervention for males with high risk of coronary heart disease: A three-year follow-up. **Prev Med** 6: 416–425, 1977
30. Blair SN, Goodyear NN, Wynne KL, Saunders RP: Comparison of dietary and smoking habit changes in physical fitness improvers and nonimprovers. **Prev Med** 13: 411–420, 1984
31. Blair SN, Jacobs DR, Powell KE: Relationships between exercise or physical activity and other health behaviors. **Publ Health Rep** 100: 172–180, 1985