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Physical Activity and Stroke Incidence in Women and Men

The NHANES I Epidemiologic Follow-up Study

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To test the hypothesis that physical inactivity is associated with increased stroke risk in women and men, the authors analyzed data from a longitudinal cohort study with three follow-up data collection waves. In the National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study, 7,895 white persons and black persons aged 45–74 years were examined in 1971–1975 as part of NHANES I. Included in this analysis were 5,852 persons without a history of stroke or missing data. The average follow-up was 11.6 years (maximum, 16.4 years). Incident stroke (fatal and nonfatal) was the main outcome measure. Events were ascertained from cause of death information coded from death certificates and from discharge diagnoses coded from hospital and nursing home records during the follow-up period (1971 through 1987). Participants were asked to characterize their level of habitual physical activity as low, moderate, or high. The relative risk for stroke was estimated by Cox proportional hazards regression analysis, comparing persons reporting low with those reporting high physical activity at baseline and persons in the upper with those in the lower tertile of resting pulse rate. There were 249 incident cases of stroke identified in white women, 270 in white men, and 104 in blacks. In white women aged 65–74 years, low nonrecreational activity was associated with an increased risk of stroke (relative risk = 1.82, 95% confidence interval 1.10–3.02) after adjusting for the baseline risk factors of age, smoking, history of diabetes, history of heart disease, education, systolic blood pressure, serum total cholesterol, body mass index, and hemoglobin concentration. Similar associations were seen for men and for blacks and for low recreational activity in women. A higher resting pulse rate was associated with an increased risk of stroke in blacks but not in whites. A consistent association of reported low physical activity with an increased risk of stroke was observed in white women. Regular physical activity may be of benefit in preventing stroke in women as well as men. *Am J Epidemiol* 1996;143:860–9.

blacks; cerebral hemorrhage; cerebral infarction; cerebrovascular disorders; cohort studies; exercise; heart rate; physical fitness

Many studies have demonstrated a protective effect of physical activity for coronary heart disease (1). Surprisingly, there have been few studies of physical activity and the risk of stroke, the third leading cause of death in the United States (2–5). Published studies are relatively few for women, blacks, and the elderly, most studies having been of middle-aged white men. Similarly, a number of studies have reported an elevated resting pulse rate to be a risk factor for coronary heart disease incidence and death (6), but no studies have examined an elevated resting pulse rate as a risk factor for stroke. A National Institutes of Health workshop specifically recommended research on the lack of exercise as a risk factor for stroke in white women and black women (7). Therefore, data from a large, national cohort were examined to test the hypotheses that low levels of recreational and nonrecreational physical activity, compared with higher levels of physical activity, and higher, compared with lower, resting pulse rates are associated with an increased risk of stroke in women and men and in blacks and whites in the United States.

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Abbreviations: CI, confidence interval; ICD-9, *International Classification of Diseases*, Ninth Revision; NHANES I, National Health and Nutrition Examination Survey I; NHEFS, NHANES I Epidemiologic Follow-up Study; RR, relative risk.

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MATERIALS AND METHODS

The National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study (NHEFS) is a longitudinal study of participants in NHANES I who were 25–74 years of age at the time of the survey examination in 1971–1975 (8–11). The

personal interviews and physical and laboratory examinations of NHANES I provided the baseline data for the NHEFS. This analysis was based on three waves of follow-up data collected during 1982–1984, 1986, and 1987. The collected data consisted of interviews, health care facility medical records for the period between baseline and last follow-up, and death certificates for all decedents. Information about the place and date of hospitalizations was obtained from the follow-up interviews and/or death certificates. The completeness of data collection has been reported (12, 13). An analysis comparing cases found by NHEFS with all Medicare hospitalizations within the same 3-year period revealed that 79 percent of the hospitalizations for stroke identified by either source were identified by NHEFS (National Center for Health Statistics, unpublished data).

Of the 7,895 white persons and black persons 45–74 years of age at baseline, 270 (3.4 percent) were lost to follow-up or had no follow-up interview or death certificate. Excluded from the analyses were 1,589 persons with unknown baseline physical activity history, resting pulse rate, systolic blood pressure, serum cholesterol, diabetes history, number of cigarettes smoked (current smokers only), hemoglobin concentration, body mass index, history of heart disease, or educational attainment. Additionally, 184 persons were excluded who had a positive history of stroke at baseline, defined as those who had ever been told by a doctor that they had a stroke prior to the baseline interview. After all exclusions, 5,852 persons remained for the analyses (5,081 white persons and 771 black persons) as shown in table 1. The mean length of follow-up for stroke-free survivors for the mortality analyses was 12 years.

Outcome definitions

Incident stroke cases met at least one of the following criteria (14): 1) a death certificate with the underlying or nonunderlying cause of death coded 431–434.9, 436, or 437.0–437.1 using the *International Classification of Diseases*, Ninth Revision (ICD-9); or 2) one or more hospital and/or nursing home stays during the follow-up period with any discharge diagnosis with these codes using the Clinical Modification of ICD-9. The date of incidence was estimated as one of the following: 1) the date of first hospital admission with a stroke diagnosis or 2) the date of death for stroke deaths without any hospital records of stroke. In the analyses of incidence, only the first event was counted in persons with multiple stroke events. In the subgroup, nonhemorrhagic stroke was defined as follows by the underlying or nonunderlying cause of death or hospital discharge diagnosis: ICD-9 codes 433–434.9, 436, or 437.0–437.1 without the associated 431–432.9 codes. The number of cases of hemorrhagic stroke (excluding subarachnoid hemorrhage) with ICD-9 codes 431–432.9 was too small for meaningful analysis within sex or race groups. Stroke deaths had a stroke ICD-9 code as listed above as the underlying cause of death.

Baseline variables

The following questions on habitual physical activity were asked: "Do you get much exercise in things you do for recreation (sports, or hiking, or anything like that), or hardly any exercise, or in between?" "In your usual day, aside from recreation, are you physically very active, moderately active, or quite inactive?" Among all whites, 45.6 percent reported low

TABLE 1. Number of incident cases of stroke and stroke deaths by race and sex in persons aged 45–74 years at baseline in the analysis cohort, NHEFS,* 1971–1987

	Cases		Deaths		No. at risk
	All stroke	Nonhemorrhagic stroke	All stroke	Nonhemorrhagic stroke	
45–64 years					
White women	53	48	6	4	1,473
White men	69	60	10	7	1,285
65–74 years					
White women	196	179	62	52	1,240
White men	201	186	53	47	1,083
45–74 years					
White women	249	227	68	56	2,713
White men	270	246	63	54	2,368
Blacks	104	94	33	29	771

* NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study.

recreational activity, and 11.7 percent reported low nonrecreational activity (appendix table 1).

The baseline medical history questionnaire provided information about selected conditions (e.g., diabetes) diagnosed by a doctor (8, 9). A positive history of heart disease at baseline was defined as having ever been told by a doctor that one had ever had a heart attack or heart failure or having used any medicine, drugs, or pills for a weak heart during the 6 months prior to the baseline interview. At the beginning of the baseline physical examination, the physician counted the radial pulse for at least 30 seconds and measured blood pressure with the examinee seated (15). Other baseline variables were measured as described elsewhere (8, 9, 15–19).

Characteristics of the persons in the analyses presented here were compared with those of the persons who were excluded. The percentage with low recreational activity among persons in the analysis was 46.5 percent, compared with 51.7 percent for those excluded because of missing data for other variables and 66.3 percent for those excluded because of a history of stroke at baseline. The percentage with low nonrecreational activity among persons in the analysis was 10.4 percent, compared with 15.6 percent for those excluded because of missing data for other variables and 35.6 percent for those excluded because of a history of stroke at baseline. Persons with missing data were more likely to be older and black but no more likely to be female than were those in the analysis. The cumulative incidence of stroke in persons in the analysis was 10.6 percent, compared with 12.3 percent among persons with no baseline history of stroke but excluded because of missing data.

Statistical methods

Stroke incidence rates were calculated as the number of incident cases per 1,000 person-years at risk. Incidence rates were age adjusted by the direct method using two age groups (45–64 and 65–74 years) and the age distribution of person-years at risk in the NHEFS cohort. Estimates of the risk of stroke incidence and of stroke death for persons with lower levels of physical activity or pulse rate relative to those with higher levels derive from Cox proportional hazards regression models computed using the PHGLM procedure in the Statistical Analysis System (20). Persons who did not develop stroke were censored at either the date of their last follow-up interview or their date of death. Tests of the significance of trends across categories of physical activity were conducted by treating the three levels of activity as ordered categories. Categories of pulse rate used in the analysis were approximate tertiles for the study population in locations 1–100. Confirmatory analyses (not shown) were also performed with the pulse rate entered as a continuous variable with a quadratic term included.

All models included the age at baseline in single years as a covariate. Possible confounders were selected based on prior evidence from NHEFS and other studies (2–4, 14). Risk-adjusted models included cigarette smoking (never, former, and 1–10, 11–20, >20 cigarettes per day), serum cholesterol (<200, 200–239, and >239 mg/dl), systolic blood pressure (mmHg), history of diabetes (yes, no), educational attainment (<12 years and ≥12 years), hemoglobin concentration (<13.9, 13.9–15.2, and >15.2 g/dl), history of heart disease (yes, no), and body mass index (kg/m^2). Multiple categorical variables were used to represent cigarette smoking, cholesterol level, and hemoglobin level. Nonlinear relations with stroke incidence for hemoglobin have been shown in earlier studies (14). Separate models were developed for white men, white women, and blacks. Models for blacks included sex as a covariate.

To assess the effect of the complex survey design on the results, we performed Cox proportional hazards regression analyses using PROC SURVIVAL in SUDAAN to incorporate the sample weights and the stratification and clustering in the analysis (21, 22). The results were consistent with minimal effects of the complex survey design on the main conclusions derived from the unweighted estimates. Therefore, the estimates from the unweighted Cox regression models are presented.

RESULTS

Recreational activity

All stroke. Table 1 shows the number of incident cases of stroke and the number of stroke deaths in the analysis cohort by sex and race. In white women, the incidence rate of stroke was highest among those reporting low recreational activity levels, intermediate among those reporting moderate activity, and lowest among those reporting high activity levels (figure 1). In white women aged 45–64 and 65–74 years, low activity was associated with increased age-adjusted stroke risk (table 2). This association was only slightly diminished and borderline significant after controlling for other risk variables. A test for linear trend in the relative risk was statistically significant at the ages of 45–64 ($p = 0.008$) and 65–74 ($p = 0.02$) years. For white women aged 45–74 years, the interaction term age × low activity was not statistically significant, despite an apparent greater effect of activity at the ages of 45–64 years than at 65–74 years.

At 65–74 years, the incidence rate of stroke was

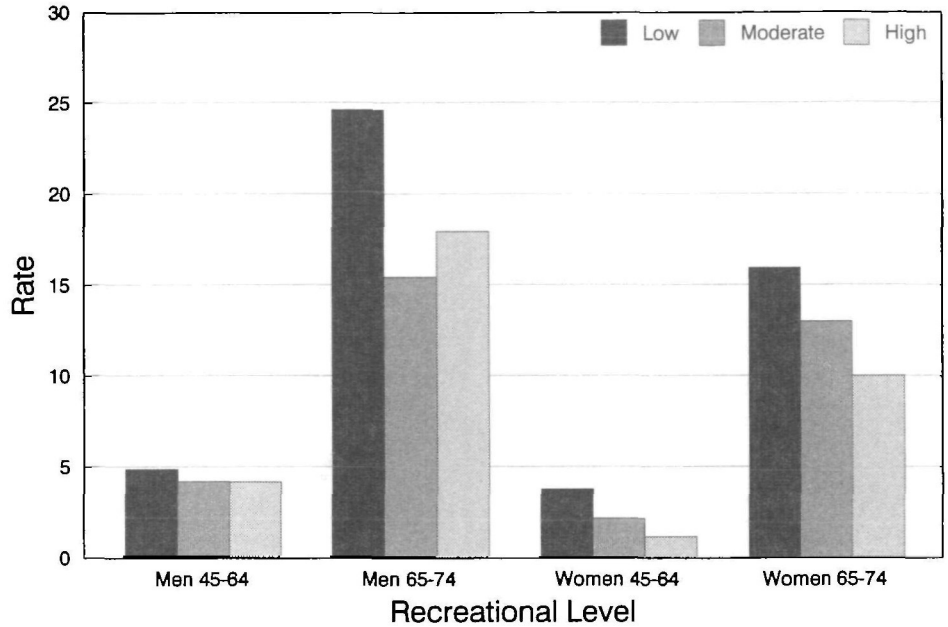

FIGURE 1. Stroke incidence rate per 1,000 person-years by age, sex, and recreational physical activity level in whites, National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study, 1971–1987.

substantially higher in white men reporting low recreational activity than in men reporting moderate or high activity levels. Little variation by activity level was seen at 45–64 years (figure 1). In white men aged 65–74 years, the risk of stroke was increased with low activity compared with high activity after adjusting for age (table 2). The relative risk was reduced when all risk variables were added to the model. Despite different apparent results for men 45–64 and 65–74 years, for men aged 45–74 years the interaction term age × low activity was not statistically significant. No significant associations of recreational activity level with stroke incidence were seen in blacks (table 3).

No significant associations of low activity with all stroke death were seen for white women or white men aged 45–74 years (e.g., for white men with low activity, the age-adjusted relative risk (RR) = 0.91, 95 percent confidence interval (CI) 0.49–1.68; for white women RR = 1.61, 95 percent CI 0.72–3.59) or for blacks.

Nonhemorrhagic stroke. A borderline significant association was seen between low activity and nonhemorrhagic stroke risk in white women aged 65–74 years (table 2). This association was diminished and no longer significant after controlling for other risk variables. However, the association was significant for the ages of 45–74 years combined (risk-adjusted RR = 1.65, 95 percent CI 1.04–2.63). Table 2 shows a significantly increased age-adjusted risk of nonhemorrhagic stroke in white men aged 65–74 years with low recreational activity; it was reduced after controlling for all risk variables. No significant associations between low recreational activity and nonhemorrhagic stroke were seen in blacks.

Nonrecreational activity

All stroke. In white women, the incidence rate of stroke was highest among those reporting low nonrecreational activity levels, intermediate among those reporting moderate activity, and lowest among those reporting high activity levels (figure 2). A significant association was seen between low activity and increased stroke incidence in white women aged 45–64 and 65–74 years (table 4). This association was slightly diminished but still significant after controlling for other risk variables. Tests for linear trend were statistically significant at the ages of 45–64 (p = 0.01) and 65–74 (p = 0.01) years, suggesting a dose-response relation. For white women aged 45–74 years, the interaction term age × low activity was not statistically significant, despite the apparent stronger association at the age of 45–64 years than at 65–74 years.

At 65–74 years, the incidence rate of stroke was substantially higher in men reporting low activity, intermediate in men with moderate activity, and lowest in men reporting high activity levels (figure 2). Little variation by activity level was seen at the ages of 45–64 years. In white men aged 65–74 years, the risk of stroke was increased with low activity compared with high activity after adjusting for age (table 4). The relative risk was reduced slightly when all risk vari-

TABLE 2. Relative risks for stroke incidence associated with recreational physical activity level in whites aged 45–74 years, NHEFS,* 1971–1987

Diagnosis and baseline physical activity level	Age adjusted		Risk adjusted†	
	RR*	95% CI*	RR	95% CI
Women				
All stroke				
45–64 years				
Moderate	1.83	0.53–6.29	1.80	0.52–6.22
Low	3.37	1.04–10.98	3.13	0.95–10.32
65–74 years				
Moderate	1.32	0.79–2.20	1.27	0.76–2.12
Low	1.68	1.03–2.73	1.55	0.95–2.53
Nonhemorrhagic stroke				
45–64 years				
Moderate	1.59	0.46–5.55	1.54	0.44–5.42
Low	3.05	0.93–9.97	2.89	0.87–9.55
65–74 years				
Moderate	1.29	0.76–2.18	1.23	0.72–2.10
Low	1.60	0.97–2.64	1.47	0.88–2.44
Men				
All stroke				
45–64 years				
Moderate	1.04	0.55–1.97	1.17	0.61–2.27
Low	1.22	0.64–2.33	1.24	0.63–2.41
65–74 years				
Moderate	0.89	0.60–1.31	0.86	0.58–1.28
Low	1.43	0.98–2.08	1.29	0.88–1.88
Nonhemorrhagic stroke				
45–64 years				
Moderate	0.99	0.51–1.95	1.16	0.58–2.32
Low	1.07	0.54–2.12	1.10	0.54–2.23
65–74 years				
Moderate	0.91	0.61–1.38	0.89	0.59–1.35
Low	1.49	1.01–2.21	1.34	0.90–2.00

* NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study; RR, relative risk; CI, confidence interval.
† Adjusted for baseline age, smoking, history of diabetes, history of heart disease, education, systolic blood pressure, serum total cholesterol, body mass index, and hemoglobin. Reference category is high physical activity.

TABLE 3. Relative risks for stroke incidence associated with physical activity level in blacks aged 45–74 years, NHEFS,* 1971–1987

Diagnosis and baseline physical activity level	Age and sex adjusted		Risk adjusted†	
	RR*	95% CI*	RR	95% CI
Recreational				
All stroke				
Moderate	1.31	0.64–2.70	1.33	0.63–2.79
Low	1.41	0.72–2.77	1.33	0.67–2.63
Nonhemorrhagic stroke				
Moderate	1.24	0.58–2.68	1.34	0.61–2.94
Low	1.43	0.71–2.91	1.43	0.70–2.94
Nonrecreational				
All stroke				
Moderate	1.44	0.94–2.22	1.40	0.90–2.16
Low	1.45	0.77–2.72	1.41	0.74–2.70
Nonhemorrhagic stroke				
Moderate	1.33	0.85–2.09	1.29	0.82–2.04
Low	1.41	0.73–2.71	1.42	0.72–2.79

* NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study; RR, relative risk; CI, confidence interval.
† Adjusted for baseline age, sex, smoking, systolic blood pressure, serum total cholesterol, history of diabetes, hemoglobin, body mass index, history of heart disease, and education. Reference category is high physical activity.

ables were added to the model. There was an apparent dose-response relation at the age of 65–74 years. A test for linear trend was significant ($p = 0.02$).

No significant associations of low nonrecreational activity with stroke incidence were seen in blacks comparing low activity with high activity (table 3).

White women and white men with low nonrecreational activity had higher total stroke death rates than did those reporting high activity (figure 3). For white women with low compared with high activity, the age-adjusted relative risk was 2.51 (95 percent CI 1.08–5.80), and the risk-adjusted relative risk was 2.33 (95 percent CI 0.98–5.54). For white men with low compared with high activity, the age-adjusted relative risk was 2.26 (95 percent CI 0.98–5.22), and the risk-adjusted relative risk was 1.92 (95 percent CI 0.83–4.46). No significant associations of low activity with stroke death were seen in blacks.

Nonhemorrhagic stroke. A significant association between low activity and nonhemorrhagic stroke was seen in white women aged 65–74 years; it was reduced after controlling for all risk variables (table 4). Analyses also revealed a significantly increased risk in white men aged 65–74 years with low activity that was reduced and still significant after controlling for all risk variables.

Pulse rate

In white women aged 45–74 years, no significant association was seen between the pulse rate and the risk of any stroke (data not shown). In white men aged 45–74 years, the risk of total stroke or nonhemorrhagic stroke was not significantly increased for a pulse rate of >84 compared with <74 beats per minute after adjusting for age and other risk variables. A significant association of the pulse rate with the risk of stroke was seen in blacks, comparing a pulse rate of >84 with a pulse rate of <74 beats per minute (age-adjusted RR = 2.14, 95 percent CI 1.31–3.51; risk-adjusted RR = 2.07, 95 percent CI 1.25–3.43). No significant associations of pulse rate with all stroke death were seen for white women or white men aged 45–74 years (e.g., for white women, the age-adjusted RR = 1.58, 95 percent CI 0.92–2.72; for white men, the age-adjusted RR = 1.26, 95 percent CI 0.70–2.28). No significant associations of the pulse rate with stroke death were seen in blacks (data not shown).

DISCUSSION

Self-reported sedentary behavior was found to be associated with an increased risk of stroke in this national cohort of women and men. This association was particularly strong and consistent in white women, for whom a dose-response relation was apparent between the activity level and stroke incidence.

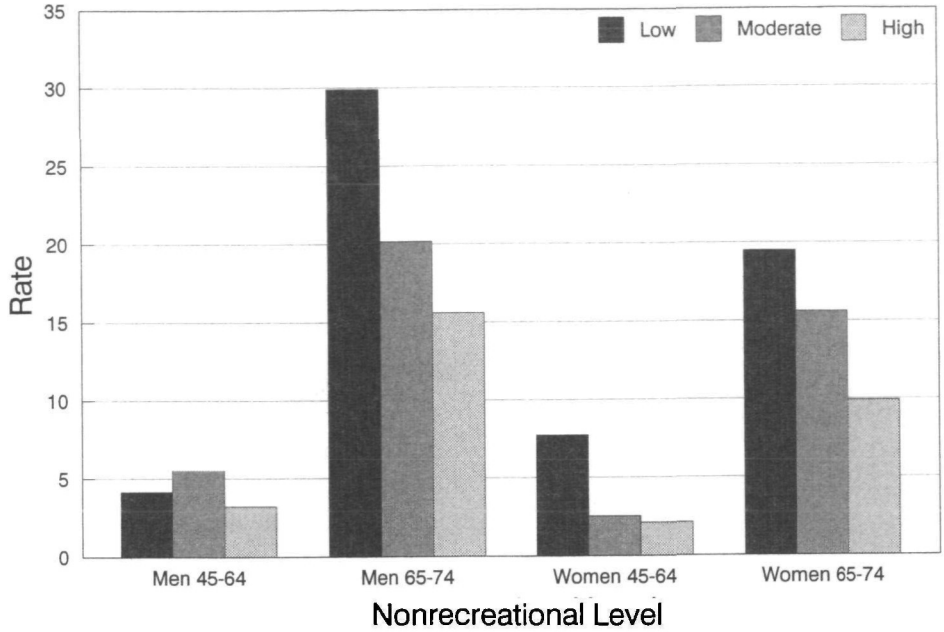

FIGURE 2. Stroke incidence rate per 1,000 person-years by age, sex, and nonrecreational physical activity level in whites, National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study, 1971–1987.

The association persisted even after controlling for multiple stroke risk factors. The association tended to be stronger for women aged 45–64 years and for nonrecreational activity. The reasons for these subgroup differences are not apparent. Despite the syntactical similarity of the two activity questions, persons reporting low nonrecreational activity were probably more sedentary than were those of the much larger group reporting low recreational activity. Only 16–25 percent of whites in various age and sex groups reporting low recreational activity also reported low nonrecreational activity. When variables for both recreational and nonrecreational activity were included in models for white women and men, only the coefficients for nonrecreational activity were statistically significant. Similar associations in blacks did not attain statistical significance, probably because of the much smaller sample. Significant associations of the pulse rate with stroke incidence were seen only in blacks.

There was no evidence for effect modification by cigarette smoking in white women in models including interaction terms or separate models for smokers and nonsmokers. In white men, the interaction terms were also not significant. However, the regression coefficient for low nonrecreational activity was smaller and not statistically significant in smokers; it was larger and statistically significant in nonsmokers. This suggests the hypothesis that high nonrecreational physical activity was less protective in white male smokers than in nonsmokers, even when the amount smoked and multiple other risk factors including education were controlled for.

Mechanisms

Physical activity is postulated to protect against coronary heart disease by reducing blood pressure, by raising high density lipoprotein cholesterol, by protecting against the deleterious effects of smoking and other risk factors, and by inducing cardiovascular fitness with attendant reductions in myocardial oxygen demand during daily life activities and stresses (23). Similar mechanisms may be postulated for protection against stroke, for which favorable effects on blood pressure, platelet aggregation, and coagulability may be particularly important. Because of the effects of physical activity on multiple risk factors, it is important to examine the age-adjusted as well as the risk-adjusted relative risk in assessing the overall impact of physical activity. Despite an association of low self-reported activity levels with higher resting pulse rates in previous analyses (24), an elevated resting pulse rate itself could not be shown to be an independent risk factor for stroke in whites in the NHEFS.

Comparisons with previous studies

Few studies were found that looked for an effect of physical activity level on stroke occurrence in women (3, 25–29). The results of most of these are consistent with those of the NHEFS. However, not all studies of physical activity and stroke in women have found a

TABLE 4. Relative risks for stroke incidence associated with nonrecreational physical activity level in whites aged 45–74 years, NHEFS,* 1971–1987

Diagnosis and baseline physical activity level	Age adjusted		Risk adjusted†	
	RR*	95% CI*	RR	95% CI
Women				
All stroke				
45–64 years				
Moderate	1.18	0.64–2.20	1.07	0.57–1.99
Low	3.79	1.82–7.87	3.51	1.66–7.46
65–74 years				
Moderate	1.52	1.08–2.13	1.42	1.01–2.00
Low	2.03	1.24–3.30	1.82	1.10–3.02
Nonhemorrhagic stroke				
45–64 years				
Moderate	1.29	0.67–2.51	1.18	0.61–2.30
Low	4.58	2.14–9.80	4.46	2.03–9.76
65–74 years				
Moderate	1.53	1.07–2.17	1.42	1.00–2.03
Low	1.95	1.16–3.27	1 74	1.02–2.97
Men				
All stroke				
45–64 years				
Moderate	1.88	1.13–3.10	1.75	1.04–2.96
Low	1.36	0.52–3.54	1.07	0.40–2.86
65–74 years				
Moderate	1.28	0.94–1.75	1.20	0.88–1.64
Low	2.08	1.32–3.27	1 82	1.15–2.88
Nonhemorrhagic stroke				
45–64 years				
Moderate	1.93	1.12–3.33	1.85	1.05–3.25
Low	1.60	0.60–4.25	1.31	0.49–3.56
65–74 years				
Moderate	1.24	0.90–1.72	1.17	0.84–1.61
Low	1.95	1.21–3.15	1.70	1.05–2.75

* NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study; RR, relative risk; CI, confidence interval.

† Adjusted for baseline age, smoking, history of diabetes, history of heart disease, education, systolic blood pressure, serum total cholesterol, body mass index, and hemoglobin. Reference category is high physical activity.

significant association (2, 25). Studies contrasting work and leisure time activity have not yielded consistent results in women or men.

In Eastern Finland, low physical activity at work was associated with an increased risk of stroke during 7-year follow-up in both women and men aged 30–59 years at baseline, even after controlling for multiple variables (26). No significant association was found for leisure time activity with stroke or myocardial infarction. Measurement of physical activity was somewhat similar to that in the NHEFS. Consistent with NHEFS results, work but not leisure-time physical inactivity was associated with increased intimal-medial carotid wall thickness on B-mode ultrasonography, an indicator of atherosclerosis, in a large, community sample aged 45–64 years (30). This association was independent of multiple risk variables in both women and men.

Results of studies in men have also been generally consistent with NHEFS findings (2, 4, 31–34). When assessed by two simple questions somewhat comparable with those of the NHEFS, inactivity at work or at home was associated with a modest excess risk of stroke that was not statistically significant in Hawaiian Japanese men (32). However, men who reported inactivity at work had a significant excess of hemorrhagic stroke.

No previous studies of the resting pulse rate and stroke risk were found.

Limitations

Limitations of the study include possible bias arising from loss to follow-up, missing data on baseline risk variables, and, for the incidence analysis, missing hospital data at follow-up. However, repeating the regression analysis for total stroke including cases of self-reported stroke without confirming hospital records at follow-up (160 in whites, 32 in blacks) produced no major changes in the results. A further source of possible bias was misclassification due to the inaccuracy of diagnoses coded on death certificates and hospital records, especially regarding stroke subgroups. Inaccuracy of the baseline history of stroke could result in cases being identified during follow-up that were actually diagnosed prior to baseline. Further, for stroke incidence, the year of onset was taken as the year of first hospitalization, but this could be in error if an earlier hospitalization for stroke was not reported or the records not found. Extensive atherosclerosis might itself cause low physical activity. Exclusion of prevalent stroke cases at baseline and controlling for a history of heart disease make this an unlikely source of bias in this analysis.

Errors in measurement of physical activity could be a source of bias, given the use of only two questionnaire items to classify persons. The questions asked for subjective, nonquantitative assessment. However, previous analyses confirmed that persons classified as highly active in NHANES I had a lower resting pulse rate than did persons reporting low activity, suggesting greater physical fitness probably due to greater habitual activity (24). Similar results were obtained in the NHEFS cohort in unpublished analyses. The difference between the mean pulse rate of persons in the NHEFS with high versus low self-reported activity tended to be greater for nonrecreational than recreational activity and for men than women. The Kendall rank-order correlation coefficients for physical activity level and pulse rate tended to be higher for nonrecreational than for recreational activity (consistent with current findings) for men than for women and for whites than for blacks. Correlation coefficients were similar for persons aged 45–64 and 65–74 years for both types of activity. Further, energy intake from dietary recall was directly correlated with the self-reported activity level in the NHEFS (35). Activity levels are not stable over long periods of time; this

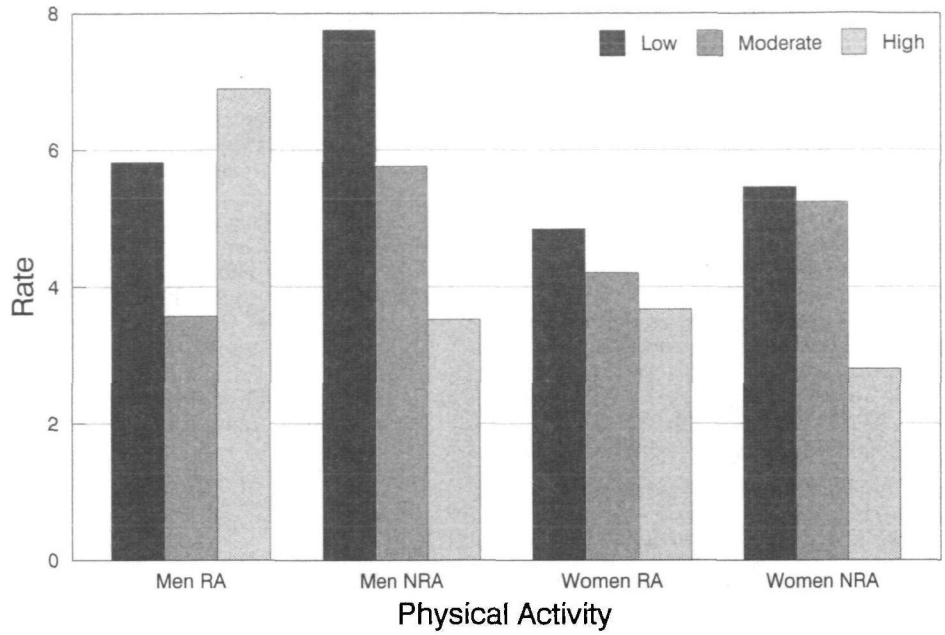

FIGURE 3. Stroke death rate per 1,000 person-years by physical activity level in white men and women aged 65–74 years, National Health and Nutrition Examination Survey I (NHANES I) Epidemiologic Follow-up Study, 1971–1987. RA, recreational activity; NRA, nonrecreational activity.

causes misclassification when only a baseline measure is used (36). Since retirement might change nonrecreational physical activity levels in some persons, data were presented separately for persons aged 45–64 and 65–74 years. It seems likely, therefore, that any bias would be toward the null, arising from random errors in the reporting or overreporting of activity. The means and distributions of multiple baseline characteristics of the NHEFS cohort by activity level have been published (35). No assessment of the type, intensity, or duration of the physical activity was possible.

Errors in measurement of other baseline variables could also result in bias, but this seems unlikely given the standardized nature of the NHANES I examination. One exception was baseline smoking data, which were derived or imputed from follow-up interview questions for about half the cohort. However, this approach has been judged valid for analyses of mortality (19). The relatively long interval between the baseline examination and the occurrence of stroke events could produce bias toward the null because of the unmeasured variation of activity over the interval. Confounding by variables not measured cannot be excluded. Statistical power was relatively low for blacks and did not permit sex-specific analyses in blacks.

Most cases of stroke occurred in persons aged 65–74 years at baseline. Although analyses of attributable risk (not shown) imply that over 27 percent of strokes in white women might be preventable by the elimination of sedentary lifestyle, this estimated benefit is probably not achievable in the elderly. Low physical activity in some of those aged over 65 years may be caused by a number of chronic disabling conditions, such as arthritis, heart disease, claudication, chronic obstructive pulmonary disease, and osteoporosis, among others (37, 38). Nevertheless, the findings regarding the effects of exercise in young adulthood and middle age and stroke (3, 33, 34), together with the low percentage of women in compliance with recommended activity levels at all ages (39), suggest that a possible role for increased physical activity in stroke prevention should be explored further.

In conclusion, in a national cohort of women and men, physical inactivity was associated with an increased risk of stroke. The association was particularly strong and consistent in white women. Future studies should assess both work and leisure time physical activity using validated instruments in population samples including women, the elderly, and blacks.

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APPENDIX

APPENDIX TABLE 1. Percentage with high, moderate, or low self-reported physical activity levels at baseline by age, sex, and race, NHEFS,* 1971–1987

Activity level	Recreational		Nonrecreational	
	45–64 years	65–74 years	45–64 years	65–74 years
White women				
High	13.7	13.2	43.7	31.6
Moderate	39.1	34.8	47.8	57.3
Low	47.3	52.1	8.5	11.1
White men				
High	20.9	19.5	47.6	35.2
Moderate	42.2	41.6	43.6	53.6
Low	36.9	38.9	8.8	11.3
Black women				
High	8.5	9.1	41.1	27.4
Moderate	22.8	18.8	46.4	51.8
Low	68.8	72.1	12.5	20.8
Black men				
High	15.4	12.2	49.7	36.5
Moderate	32.0	32.0	41.4	48.6
Low	52.7	55.8	8.9	14.9

* NHEFS, National Health and Nutrition Examination Survey I Epidemiologic Follow-up Study.