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Relationship of Physical Activity and Body Mass Index to the Risk of Hypertension: A Prospective Study in Finland

Gang Hu, Noël C. Barengo, Jaakko Tuomilehto, Timo A. Lakka, Aulikki Nissinen, Pekka Jousilahti

Abstract—Prospective studies on physical activity in relation to the risk for hypertension are scant, particularly in women. This study aimed at finding out whether regular physical activity can reduce the risk of hypertension in both men and women, and in subjects with and without overweight. We prospectively followed 8302 Finnish men and 9139 women aged 25 to 64 years without a history of antihypertensive drug use, coronary heart disease, stroke, and heart failure at baseline. Both single and joint associations of physical activity and body mass index with the risk of hypertension were examined using Cox proportional hazard models. During a mean followup of 11 years, there were 1600 incident cases of drug-treated hypertension. Multivariate-adjusted hazards ratios of hypertension associated with light, moderate, and high physical activity were 1.00, 0.63, and 0.59 in men ($P_{\text{trend}} < 0.001$), and 1.00, 0.82, and 0.71 in women ($P_{\text{trend}} = 0.005$), respectively. This association persisted both in subjects who were overweight and in those who were not. Multivariate-adjusted hazards ratios of hypertension based at different levels of body mass index (< 25 , 25 to 29.9 , and ≥ 30) were 1.00, 1.18, and 1.66 for men ($P_{\text{trend}} < 0.001$), and 1.00, 1.24, and 1.32 for women ($P_{\text{trend}} = 0.007$), respectively. Further adjustment for baseline systolic blood pressure did not affect the protective effect associated with physical activity, but it weakened markedly the association between body mass index and hypertension. The present study indicates that regular physical activity and weight control can reduce the risk of hypertension. The protective effect of physical activity was observed in both sexes regardless of the level of obesity. (*Hypertension*. 2004;43:25-30.)

Key Words: exercise ■ body mass index ■ obesity ■ blood pressure ■ hypertension

There is good evidence that regular physical activity reduces the risk for cardiovascular diseases.¹⁻⁴ Part of this effect is thought to be mediated through reduced blood pressure (BP), improved lipid metabolism, and decreased body weight.² Even though results from clinical trials^{5,6} and cross-sectional studies⁷⁻⁹ have indicated that physical activity or aerobic exercise are inversely associated with BP, the evidence of such an association from the prospective studies is still scant. Only five prospective studies have demonstrated that regular physical activity is related to a reduced risk of hypertension in men,¹⁰⁻¹⁴ but not in women.^{12,14} Evidence from epidemiological studies has concluded that being overweight, obesity and weight gain are associated with an increased risk of hypertension.^{7,15-17} None of the previous studies, however, examined the joint association of physical activity and body mass index (BMI) on the risk for hypertension. The aim of this study is to examine the single and joint association of physical activity and BMI with risk of hypertension in a large prospective cohort study.

Methods

Participants

Baseline surveys were performed in random samples of the population from four areas in Finland in 1982, 1987, and 1992 according to the Monitoring Trends and Determinants in Cardiovascular Disease Protocol.¹⁸⁻²⁰ A total of 21 630 subjects aged 25 to 64 years participated in the surveys. The participation rate varied by year from 74% to 88%.²⁰ The final study cohort comprised 8302 men and 9139 women, excluding subjects who received drug treatment for hypertension according to the National Social Insurance Institution's register for the reimbursement of drug costs ($n=2072$) before the baseline survey, as well as those who reported that they used antihypertensive drugs ($n=1130$), subjects with a history of coronary heart disease ($n=367$), stroke ($n=131$), or heart failure ($n=291$), subjects who were physically inactive because of disease or disability ($n=148$) at baseline, and subjects with incomplete data on physical activity or any other variable required in analyses ($n=50$). These surveys were conducted according to the ethical rules of the National Public Health Institute and the investigations were performed in accordance with the Declaration of Helsinki.

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TABLE 1. General Characteristics of Study Subjects at Baseline by the Outcome During the Follow-Up

Variable	Men		P Value*	Women		P Value*
	No Hypertension (n=7515)	Hypertension (n=787)		No Hypertension (n=8326)	Hypertension (n=813)	
Age, y	42.9	44.8	<0.001	43.2	45.5	<0.001
Body mass index, kg/m ²	26.1	27.0	<0.001	25.4	26.3	<0.001
Diastolic blood pressure, mm Hg	84	93	<0.001	79	87	<0.001
Systolic blood pressure, mm Hg	139	151	<0.001	133	147	<0.001
Education, y	10.1	9.4	<0.001	10.5	9.5	<0.001
Alcohol, g/week	73.3	74.1	0.855	20.6	19.2	0.337
Smoking, %			0.002			0.003
Never smoker	36.4	32.4		68.4	74.0	
Ever-smoker	30.6	36.8		15.6	12.5	
Current smoker	33.0	30.7		16.0	13.4	
Body mass index class, %			<0.001			<0.001
<25	40.7	32.9		54.0	44.6	
25–29.9	45.6	47.1		31.4	36.8	
≥30	13.6	19.9		14.5	18.6	
Physical activity, %			0.001			0.003
Low	7.3	11.6		11.6	15.1	
Moderate	37.6	37.4		38.5	39.9	
High	55.0	51.1		50.0	45.0	

*t test was used for continuous variables and χ^2 test for categorical variables.

Measurements

A self-administered questionnaire was mailed to the participants to be completed at home. The questionnaire included questions on medical history, socioeconomic factors, physical activity, alcohol intake, and smoking habits. Education level, measured as the total number of school years, was divided into birth cohort-specific tertiles. The participants were classified into three smoking categories: current smokers, ex-smokers, and nonsmokers. Alcohol consumption was categorized into two categories: drinkers and non-drinkers. Physical activity included occupational, commuting, and leisure time physical activity. A detailed description of the questions is presented elsewhere,^{21,22} and they have been evaluated previously.^{9,23}

The subjects reported their occupational physical activity according to the following two categories: (1) light, which was considered physically very easy, sitting office work (eg, secretary), and (2) moderate or active, which included standing, walking, walking and lifting, or heavy manual labor (eg, store assistant, industrial work, or farm work). The daily commuting return journey was categorized into two categories: walking or bicycling <30 minutes and walking or bicycling ≥30 minutes. Self-reported leisure time physical activity was classified into two categories: (1) low, defined as almost completely inactive (eg, reading, watching TV, or doing some minor physical activity but not of moderate or high level), and (2) moderate or high, which was doing some physical activity >4 hours a week (eg, walking, cycling, light gardening, fishing, hunting) but excluding travel to work, or performing vigorous physical activity >3 hours a week (eg, running, jogging, skiing, swimming, ball games, heavy gardening, regular exercise) or competitive sports several times a week. Occupational, commuting, and leisure time physical activity were merged and regrouped into three categories: (1) low, defined as subjects who reported light levels of occupational, commuting (<30 minutes), and leisure time physical activity; (2) moderate, defined as subjects who reported only one of the three types of moderate-to-high physical activity; and (3) high, defined as subjects who reported two or three types of moderate-to-high physical activity.

At the study site, specially trained nurses measured height, weight, and BP using a standardized protocol.¹⁸ The subjects were classified in three BMI categories: <25 kg/m² (reference group), 25 to 29.9 kg/m² (overweight), and ≥30 kg/m² (obese).

Diagnosis of Hypertension

Data on the initiation of new hypertension treatment, which was the end point of the study, were received from the records of the Social Insurance Institution's nationwide register on persons entitled to special reimbursement for antihypertensive drugs. In principle, every resident in Finland has been entitled to such a reimbursement since 1970. To obtain an approval for it, the diagnosis of hypertension must be assigned by the patients' own physician on the basis of the WHO criteria for hypertension. The physician's statement documenting the details of the diagnosis of hypertension is then reviewed by the expert physician of the Social Insurance Institution. Computerized record linkage was done using the national personal identification number assigned for every person living permanently in Finland. The followup of the study cohort continued until the end of February 1998.

Statistical Analyses

SPSS for Windows 11.0 was used for statistical analysis. Standard *t* tests and χ^2 tests were used to compare the mean levels of continuous variables and the prevalence of categorical variables between subjects with and without incident hypertension. The Cox proportional hazards model was used to estimate the single or joint effect of different levels of physical activity and BMI on the risk for the incidence of hypertension. The analyses were first performed adjusting for age, area, and study year, and then further for education, smoking status, alcohol intake, history of diabetes at baseline, BMI, and systolic BP.

Results

During a mean followup period of 11 years, 787 men and 813 women developed an incident of hypertension. General char-

TABLE 2. Hazards Ratios of Hypertension According to Different Levels of Physical Activity, With Various Forms of Adjustment

Physical Activity	No. of Incident Cases of Hypertension	Person-Years	Adjusted Hazards Ratios (95% Confidence Interval)		
			A*	B†	C‡
Men					
Low	91	6628	1.00	1.00	1.00
Moderate	294	33471	0.64 (0.50–0.81)	0.63 (0.50–0.80)	0.60 (0.47–0.76)
High	402	50775	0.60 (0.47–0.75)	0.59 (0.47–0.74)	0.59 (0.47–0.74)
<i>P</i> value for trend			<0.001	<0.001	<0.001
Women					
Low	123	11855	1.00	1.00	1.00
Moderate	324	38347	0.82 (0.66–1.00)	0.82 (0.67–1.01)	0.80 (0.65–0.99)
High	366	50068	0.71 (0.58–0.87)	0.71 (0.58–0.88)	0.72 (0.58–0.88)
<i>P</i> value for trend			0.003	0.005	0.006

*Data adjusted for age, area and study year.

†Adjusted for age, area, study year, education, smoking status, alcohol intake, diabetes at baseline, and body mass index.

‡Adjusted for age, area, study year, education, smoking status, alcohol intake, diabetes at baseline, body mass index, and systolic blood pressure.

acteristics of the study population at baseline are given in Table 1. Patients who developed hypertension during the follow-up were slightly older, their BMI and baseline BP were higher, and they had less education years, were less often smokers, less physically active, and more often obese or overweight as compared with those who remained free of hypertension.

Table 2 shows single hazards ratios of hypertension for different levels of physical activity. The age-, area-, and study year-adjusted hazards ratios for hypertension associated with light, moderate, and high physical activity were 1.00, 0.64, and 0.60 in men ($P<0.001$ for trend), and 1.00, 0.82, and 0.71 in women ($P=0.003$ for trend), respectively. After further adjustments for education, smoking, alcohol intake, history of diabetes, BMI, and systolic BP at baseline, this inverse relation did not appreciably change.

Multivariate-adjusted (age, area, study year, education, smoking, alcohol intake, physical activity, and history of diabetes at baseline) hazards ratios for hypertension based on different levels of BMI of <25 , 25 to 29.9, and ≥ 30 were 1.00, 1.18, and 1.66 for men ($P<0.001$ for trend), and 1.00, 1.24, and 1.32 for women ($P=0.007$ for trend), respectively (Table 3). After a further adjustment for baseline systolic BP, this direct association decreased and became marginally significant among men ($P=0.055$ for trend) and nonsignificant among women ($P=0.150$ for the trend).

The joint associations of different levels of physical activity and BMI with the risk of hypertension are shown in Figures 1 and 2. The inverse association between physical activity and risk of hypertension was persistent in overweight and not overweight subjects. In comparison with overweight persons who reported low level of phys-

TABLE 3. Hazards Ratios of Hypertension According to Different Levels of Body Mass Index, With Various Forms of Adjustment

Body Mass Index, kg/m ²	No. of Incident Cases of Hypertension	Person-Years	Adjusted Hazards Ratios (95% Confidence Interval)		
			A*	B†	C‡
Men					
<25.0	259	37147	1.00	1.00	1.00
25–29.9	371	41463	1.21 (1.03–1.42)	1.18 (1.01–1.39)	1.13 (0.96–1.33)
≥30	157	12264	1.74 (1.42–2.14)	1.66 (1.35–2.04)	1.28 (1.04–1.58)
<i>P</i> value for trend			<0.001	<0.001	0.055
Women					
<25.0	363	54213	1.00	1.00	1.00
25–29.9	299	31903	1.25 (1.07–1.47)	1.24 (1.05–1.46)	1.13 (0.96–1.33)
≥30	151	14154	1.37 (1.12–1.68)	1.32 (1.07–1.62)	0.95 (0.77–1.17)
<i>P</i> value for trend			0.003	0.007	0.150

*Data adjusted for age, area, and study year.

†Adjusted for age, area, study year, education, smoking status, alcohol intake, diabetes at baseline, and physical activity.

‡Adjusted for age, area, study year, education, smoking status, alcohol intake, diabetes at baseline, physical activity, and systolic blood pressure.

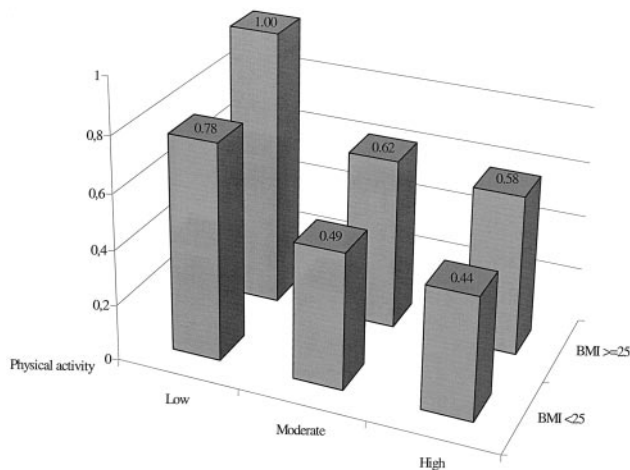


Figure 1. Hazards ratios of hypertension according to the physical activity level (low, moderate, and high) and body mass index (<25 and ≥25) among men. Adjusted for age, area, study year, education, smoking status, alcohol intake, and diabetes.

ical activity, subjects who reported both a high level of physical activity and had normal weight showed a 56% lower risk for the development of hypertension in men and a 46% lower risk in women.

Discussion

Our analysis addressed both the single and joint association of physical activity and BMI for the risk of hypertension. Regular physical activity was associated with a significantly reduced risk for hypertension in men and women, independent of age, education, smoking habits, alcohol intake, history of diabetes, BMI, and systolic BP at baseline. Overweight and obese subjects were also associated with an increased risk of hypertension. The protective effect of physical activity was consistent in both overweight and normal weight subjects.

Analyses from cross-sectional studies have indicated that physical activity is inversely associated with BP level and the prevalence of hypertension.⁷⁻⁹ However, studies on

the prospective association of regular physical activity with the risk of hypertension are scant and the results inconsistent. A meta-analysis, which included 54 clinical trials comprising 2419 participants, assessed the effect of aerobic exercise on BP.⁶ Aerobic exercise was associated with a significant reduction in mean systolic BP by 3.8 mm Hg and diastolic BP by 2.6 mm Hg. A reduction in BP was associated with aerobic exercise in both hypertensive and normotensive subjects, and both overweight and normal weight participants. Because the BP reduction related to aerobic exercise did not significantly differ among trials with various types, frequencies, and intensities of exercise intervention, the result from this meta-analysis indicated that all forms of exercise seemed to be effective in reducing BP. A prospective study among Harvard male alumni reported that men who did not participate in vigorous exercise had a 35% higher incidence of hypertension than those who were more active.¹⁰ Another Finnish study found a reduced risk for hypertension in men participating in vigorous physical activity.¹² The Atherosclerosis Risk in Community Study (ARIC) pointed out that leisure time physical activity reduced the risk of hypertension in middle-aged white men, but not in black men.¹⁴ Recently, a Japanese prospective study showed that the duration of walking to and from work and regular leisure time physical activity at least once a week decreased the risk for hypertension in Japanese men.¹³ Blair et al reported a 52% excess risk of hypertension for people with low levels of physical fitness when compared with highly fit persons.¹¹ Only two prospective studies assessed the association of physical activity with the risk of hypertension in men and women separately, and no significant association was found among women.^{12,14} The present study is, to our knowledge, the first one that has found the inverse association between physical activity and the risk for hypertension in both sexes.

The decrease in BP induced by physical activity may be explained by decreased stroke volume and contractility of the heart after exercise,²⁴ combined with the decreased systemic vascular resistance²⁵ caused by decreased sympathetic activity. Other suggested mechanisms include reduced levels of plasma renin activity and catecholamines,²⁶ as well as increased urinary sodium excretion and insulin sensitivity.²⁷

Overweight, obesity, and weight gain have been shown to be important and independent risk factors for the development of hypertension.¹⁵⁻¹⁷ Overweight and obese people are usually less active than people of normal weight.^{8,28} It has been hypothesized that increasing physical activity might reduce BP through decreased body weight or favorable changes in body fat distribution.²⁹ We found that being overweight was associated with an increased risk of hypertension in subjects at any level of physical activity. High physical activity was associated with a lower risk of hypertension, independent of baseline BMI. Furthermore, the protective effect of physical activity was consistent in both overweight and normal weight subjects. Provided that our finding represents a causal relationship between physical activity and the incidence of

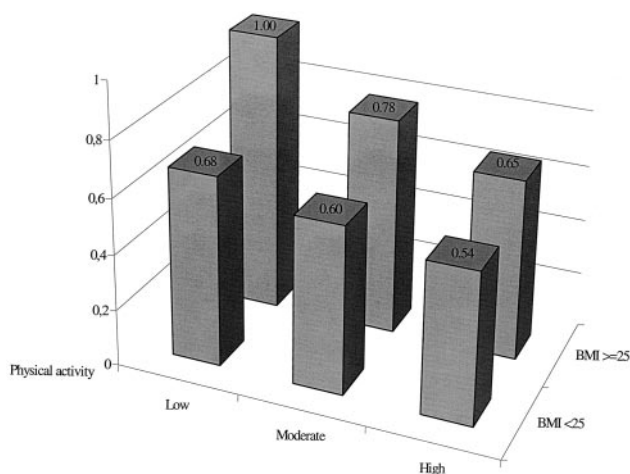


Figure 2. Hazards ratios of hypertension according to the physical activity level (low, moderate, and high) and body mass index (<25 and ≥25) among women. Adjusted for age, area, study year, education, smoking status, alcohol intake, and diabetes.

hypertension, physical activity should be considered as an important measure for the prevention of hypertension among overweight and obese persons. Weight reduction in overweight and obese people reduces the risk of hypertension, but it is well known that weight reduction in obese people is not easy, and even at best, only a limited weight reduction may be achieved.³⁰ Therefore, it is important to identify other ways to reduce the risk of hypertension. Physical activity seems to be a useful approach in this respect. The recent Finnish Diabetes Prevention Study showed that, in overweight subjects with glucose intolerance who received intensified lifestyle intervention (diet intervention and moderate exercise for at least 30 minutes per day), the long-term reduction in body weight was ~3 to 3.5 kg compared with control subjects.³¹ This intervention resulted not only in a marked reduction in the risk of developing type 2 diabetes, but also in a significant drop in blood pressure (4 mm Hg for systolic BP and 2 mm Hg for diastolic BP compared with control subjects).

Limitations of our study are mainly those in epidemiological studies in general. The assessment of habitual physical activity is always imprecise. Misclassification is inevitable and usually results in an underestimation of the association of physical activity with the risk of hypertension. Possible individual changes in the level of physical activity during the follow-up may also have influenced the results. In addition, physically active people may have a healthier lifestyle in general compared with sedentary people. Even though our analyses were adjusted for smoking and alcohol intake, residual confounding due to lifestyle factors cannot be excluded. Although we used the drug register data on hypertension treatment as the study end point, we did not have data on hypertensive people not treated with drugs. Because most hypertensive patients will start using antihypertensive drugs sooner or later, our design may mainly have affected the time of diagnosis rather than the actual risk of the disease.

Perspectives

There is increasing epidemiological evidence that regular physical activity reduces the risk of cardiovascular disease. A variety of organizations, including Centers for Disease Control and Prevention and the American College of Sports Medicine, National Institutes of Health, and the World Health Organization have suggested that every adult in the United States should have at least 30 minutes of moderate-intensity physical activity (such as brisk walking, cycling, swimming, home repair, or yard work) on most, preferably all, days of the week.^{2,32} Our study is consistent with this recommendation, and confirms that practicing regular physical activity and keeping body weight normal will protect against the development of hypertension in both middle-aged men and women. Regular physical activity is an important approach in the prevention of hypertension in normal weight and overweight or obese individuals.

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