ORIGINAL INVESTIGATION

Daily Life Activity and the Risk of Developing Hypertension in Middle-aged Japanese Men

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Background: Although previous studies suggest that physical activity may reduce the risk of hypertension, the role of daily life activity in the development of hypertension remains unclear.

Methods: The study population included 2548 Japanese male office workers aged 35 to 59 years, who were without hypertension (systolic blood pressure [SBP] <140 mm Hg, diastolic blood pressure [DBP] <90 mm Hg, and no medication for hypertension) and had no history of cardiovascular disease. Daily life energy expenditure was estimated by a 1-day activity record during an ordinary weekday at study entry. Blood pressures were measured at periodic annual health examinations over 7 successive years.

Results: After controlling for potential predictors of hypertension (age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise at entry, and change in body mass index during the follow-up period), mean SBP and DBP in each follow-up year decreased as daily life energy expenditure increased. With additional adjustment for SBP at entry, the relative risk of hypertension (SBP ≥140 mm Hg and/or DBP ≥90 mm Hg or medication for hypertension) across quartiles of daily life energy expenditure (lowest to highest) were 1.00, 0.84, 0.75, and 0.54 ($P<.001$ for trend). Analyses by presence or absence of a risk factor demonstrated that the risk of hypertension was inversely related to daily life energy expenditure in men at either low or high risk of hypertension. Daily life energy expenditure was also associated with reduced risk of hypertension for subjects in all 3 categories of normotension: low normal, normal, and high normal.

Conclusions: Increased daily life activity is effective for the prevention of hypertension, and this benefit applies to men at either low or high risk of hypertension.

Arch Intern Med. 2005;165:214-220

POOR LIFESTYLE IS PROMINENT in the causal constellation for risk factors predisposing to cardiovascular disease, and therefore interest in lifestyle modification, including increased physical activity, has grown.[1-3] Previous epidemiological studies have demonstrated that physical activity or physical fitness reduces the risk of cardiovascular disease, particularly coronary heart disease,[4-6] possibly in part by lowering blood pressure. Meta-analyses of controlled intervention trials identified a significant reduction of systolic blood pressure (SBP) and diastolic blood pressure (DBP) in normotensive and hypertensive persons assigned to aerobic exercise compared with controls,[7,8] while prospective cohort studies have generally demonstrated that physical activity or physical fitness is associated with a reduced risk of hypertension.[9-14] A prospective study among Harvard College alumni reported that men who did not engage in moderately vigorous sports play during the 1960s had a 35% greater risk of hypertension by 1972 compared with those who did.[9] Another Finnish study found that the age-adjusted relative risk of hypertension over 10 years of follow-up was 60% to 70% higher for sedentary men than for the most active people.[10] The Atherosclerosis Risk in Community Study (ARIC)[11] found that white men in the highest quartile of leisure activity (primary cycling and walking) had a 34% lower risk of developing hypertension over 6 years. Blair et al[12] reported that persons with low levels of physical fitness (72% of the group) had a 52% excess risk of hypertension for 1 to 12 years compared with highly fit persons. A prospective study in Japan 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] Recently, a prospective study in Finland observed the pro-

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Financial Disclosure: None.

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tective effect of regular physical activity in both sexes regardless of the level of obesity.[14] Most of these prospective studies have examined the relationship between specific physical activities such as walking, leisure-time physical activity, and more vigorous activities and the risk of hypertension. Recent reviews[15,16] have emphasized the importance of the total amount of physical activity rather than its specific characteristics, such as intensity, frequency, and bout duration for health benefits. This has been observed with regard to mortality, morbidity, and several disease risk factors.

Because daily life activities represent the accumulation of complex behaviors in daily life and few middle-aged individuals engage in physical training or physical activity at their jobs or during leisure time, it is important to examine whether overall physical activity in daily life contributes to a reduction of the risk of hypertension. The present study therefore prospectively examines the relationship of overall physical activity in daily life to the risk of developing hypertension in normotensive Japanese male office workers over a 7-year observation period. Because age, overweight, obesity, alcohol intake, and high-normal blood pressure are closely associated with an increased risk of developing hypertension in this cohort[17-19] and these correlates (including family history of hypertension, cigarette smoking, and regular physical exercise) may modify the association between daily life activity and the risk of developing hypertension, we also examined whether daily life activity is an important approach in the prevention of hypertension among men at either low or high risk of hypertension.

METHODS

PARTICIPANTS

To evaluate the association of daily life activity with the development of hypertension, a survey of the incidence of hypertension was done between 1994 and 2001 among Japanese men who were office workers at one of the biggest building contractors in Japan. All Japanese male office workers aged 35 to 59 years in May 1994 were invited to participate in annual health examinations (n=3694); the participation rate was 99.6% (n=3681). The Industrial Safety and Health Law in Japan requires the employer to conduct annual health examinations of all employees; the employee data, which are anonymous, are available for research with the approval of the employer. An institutional review committee approved this study, and we interpreted the return of a self-administered questionnaire signed by the subjects as their consent to participate.

Of the 3681 potential participants, 46 (1.2%) did not return the activity record or did not complete the record. Of the other subjects, 1036 (28.5%) were excluded: 1023 (28.1%) had hypertension and 28 (0.8%) had a history of either coronary heart disease or stroke. Thus, the hypertension-free population consisted of 2599 men, who reexamined over 7 successive years until May 2001. Because we also excluded 51 men who did not participate in consecutive annual health examinations, the final study population for analysis therefore consisted of 2548 men. Men in whom hypertension was found during repeated surveys through May 2001 were defined as having incident cases of hypertension. Also, 117 participants who started taking medication for hypertension during the observation period were considered to have incident cases of hypertension.

STUDY DESIGN

The participants were asked to fast for at least 8 hours and to avoid heavy physical activity for more than 2 hours before the examinations. Blood pressure was measured by technicians properly trained for measuring blood pressure for epidemiological surveys at annual health examinations in May from 1994 to 2001.[20] Both SBP and DBP were measured to the nearest 2 mm Hg with a standard sphygmomanometer on the right arm of subjects sitting after a 5-minute rest. Hypertension was defined as an SBP of 140 mm Hg or higher and/or a DBP of 90 mm Hg or higher or receipt of antihypertensive medications.[1,2] Blood pressure associated with normotension was divided into the following 3 categories: (1) low-normal blood pressure was defined as an SBP lower than 120 mm Hg and a DBP lower than 80 mm Hg, (2) high-normal blood pressure was defined as an SBP between 130 and 139 mm Hg or a DBP between 85 and 89 mm Hg or both, and (3) normal blood pressure was defined as blood pressures between the first 2 categories.

Annual health examination items at study entry included medical history, physical examination, anthropometric measurements, biochemical measurements, and an activity record for the assessment of daily life energy expenditure as well as a questionnaire on health-related behavior, such as physical exercise, smoking, and alcohol consumption. Medical history and use of prescription drugs were assessed by the examining physicians. A family history of hypertension was defined as having a mother, father, sister, and/or brother with diagnosed hypertension. Body mass index (BMI) was used as a measure of overall obesity. Blood samples were drawn from an antecubital vein. Serum total cholesterol, high-density lipoprotein cholesterol, and triglyceride and fasting plasma glucose levels were measured with Olympus AU-5000 equipment (Olympus Japan Co Ltd, Tokyo, Japan) at FALCO Biosystems Tokyo Ltd (Tokyo) according to standard laboratory procedures.[21,22] As for daily life energy expenditure, a 1-day activity record during an ordinary weekday was designed to estimate energy expenditure. The activity record for 1 day was divided into 96 periods of 15 minutes each.[23] We predefined 20 typical daily life physical activities on weekdays in this population (**Table 1**), and participants were asked to write the categorical values that correspond best to the dominant activity of each 15-minute period in the space provided. Approximate energy cost for each category in kilocalories per kilogram per 15-minute period for Japanese men was used to compute the daily life energy expenditure for each individual.[24] If an activity could not be assigned to one of the predefined categories, the subjects were asked to describe the activity in more detail. Physical exercise was not included in daily life activity because four fifths of the participants who engaged in physical exercise at least once a week exercised on the weekend. Daily energy expenditure was computed by multiplying the amount of time spent on specific daily physical activities by the energy cost per physical activity and per unit.

As for health-related behavior, data on regular physical exercise, smoking habits, and alcohol intake were obtained by interview. Participants were asked about the type and frequency on a weekly basis of leisure time physical activity. Physical exercise was defined as participation in any physical activity, such as jogging, cycling, swimming, or tennis, that was performed long enough to cause sweating. The questionnaire also asked about cigarette smoking habits (never, past, or current smoker); past or current smokers were asked to specify the number of cigarettes smoked per day and the duration of smoking in years. The questions about alcohol intake included items about the type of alcoholic beverage, the frequency of alcohol consumption per week, and the usual amount consumed daily. Weekly alcohol intake was calculated and then converted to daily alcohol consumption (grams of ethanol per day) by using standard Japanese tables.

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STATISTICAL ANALYSIS

Data are reported as mean±SD, except when the distribution was strongly skewed, in which case the median (interquartile range) is given. One-way analysis of variance and the χ^2 test were used to analyze the statistical differences among characteristics of the study participants at enrollment according to quartile of daily life energy expenditure. Categories of daily life energy expenditure were defined by the following quartiles: less than 33.3 kcal/kg per day, 33.3-36.9 kcal/kg per day, 37.0-40.3 kcal/kg per day, and 40.4 kcal/kg per day or greater. For each participant, person-years of follow-up were calculated from the date of enrollment to the date of the diagnosis of hypertension or the date of last follow-up, whichever came first. Follow-up time included 96.4% of the total potential person-years of follow-up. Changes in SBP and DBP during the follow-up period among categories of daily life energy expenditure were tested by a generalized linear model analysis. Cox proportional hazards models were used to evaluate the association of daily life energy expenditure level with development of hypertension. Data were adjusted for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise, SBP at entry, and change in BMI during the follow-up period. Potential confounding factors, except for age, SBP, and change in BMI, were treated as categorical variables: family history of hypertension (no or yes); alcohol consumption (graded as 1 [none] or as quartile 1 [grade 2] to quartile 4 [grade 5] for drinkers); cigarette smoking (graded as 1 [none] or as quartile 1 [grade 2] to quartile 4 [grade 5] for current smokers); and regular physical exercise (graded from 1 to 3 [hardly ever, once a week, or twice or more a week]). The linear trends of risks were evaluated by entering indicators for each category of exposure. The interactions of daily life energy expenditure and each of potential risk factors were tested by introducing product terms to models with the original variables.

Data were analyzed by using the SPSS/PC statistical package (SPSS Inc, Chicago, Ill). All reported *P* values are 2 tailed, and $P<.05$ was considered statistically significant.

Table 1. Estimated Energy Expenditure by an Activity Group for Japanese Men

Activity Groups and Samples Activities	Energy Expenditure, kcal/kg per 15 min
Sleeping	0.26
Rest, talking (sedentary)	0.35
Reading, writing, watching television	0.35
Talking (standing position)	0.38
Taking meals	0.41
Dressing, washing face, toilet use	0.44
Driving	0.44
Clerical work (word processor, office automation tools, bookkeeping)	0.45
Riding on vehicles (train, bus: standing position)	0.57
Slow walking (<4 km/h) (shopping, taking a walk)	0.69
Light manual work (half-sitting or standing position)	0.83
Do-it-yourself activities, gardening	0.83
Walking at normal pace (4 km/h) (commuting, shopping)	0.86
Taking a bath	0.92
Cycling (<10 km/h) (commuting, on business, shopping)	0.99
Going down stairs	1.10
Brisk walking (<4 km/h) (commuting, on business, shopping)	1.23
Manual work at moderate pace (eg, loading and unloading goods)	1.43
Climbing up/going down stairs	1.52
Climbing up stairs	2.03

RESULTS

Table 2 gives the baseline characteristics of the study sample according to quartile of daily life energy expenditure. Men in the lowest quartile of daily energy expenditure were the oldest. Mean BMI, SBP, DBP, total cholesterol level, triglyceride level, and fasting plasma glucose level, and the percentage of participants who had a family history of hypertension decreased with an increase in daily life energy expenditure. In contrast, high-density lipoprotein cholesterol level and the percentage of those who exercised at least once a week increased with an in-

Table 2. Baseline Characteristics of 2548 Hypertension-Free Japanese Male Office Workers by Quartile of Habitual Physical Energy Expenditure*

	Habitual Physical Energy Expenditure, kcal/kg per Day				
Characteristic	<33.3 (n = 637)	33.3-36.9 (n = 637)	37.0-40.3 (n = 637)	≥40.4 (n = 637)	*P* Value
Age, y	47.4 ± 6.1	46.7 ± 6.1	46.0 ± 6.1	46.0 ± 6.0	<.001
Family history of hypertension, %	31.6	30.5	30.3	26.1	.04
Current drinker, %	83.8	84.8	85.7	86.3	.61
Current smoker, %	51.5	48.0	52.6	54.0	.18
Physical exercise at least once a week, %	46.3	52.1	57.0	55.3	.001
BMI	25.6 ± 2.2	23.7 ± 1.7	22.4 ± 1.7	21.0 ± 2.0	<.001
Systolic blood pressure, mm Hg	124.2 ± 9.4	121.8 ± 10.4	120.7 ± 10.6	119.5 ± 10.6	<.001
Diastolic blood pressure, mm Hg	75.9 ± 7.9	74.1 ± 8.3	73.5 ± 8.4	72.0 ± 8.3	<.001
Total cholesterol, mg/dL	198.7 ± 32.5	194.6 ± 31.5	188.9 ± 30.6	186.8 ± 30.4	<.001
High-density lipoprotein cholesterol, mg/dL	48.6 ± 10.9	52.6 ± 12.9	55.2 ± 12.9	59.2 ± 14.1	<.001
Triglycerides, mg/dL, median (IQR)	131 (92-197)	107 (75-154)	95 (68-137)	80 (58-114)	<.001
Fasting plasma glucose, mg/dL	93.8 ± 14.3	93.7 ± 16.9	91.5 ± 14.2	91.4 ± 13.2	.009

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); IQR, interquartile range.

SI conversion factors: To convert glucose to millimoles per liter, multiply by 0.0555; to convert cholesterol to millimoles per liter, multiply by 0.0259; to convert triglycerides to millimoles per liter, multiply by 0.0113.

*Data are given as mean ± SD unless otherwise indicated.

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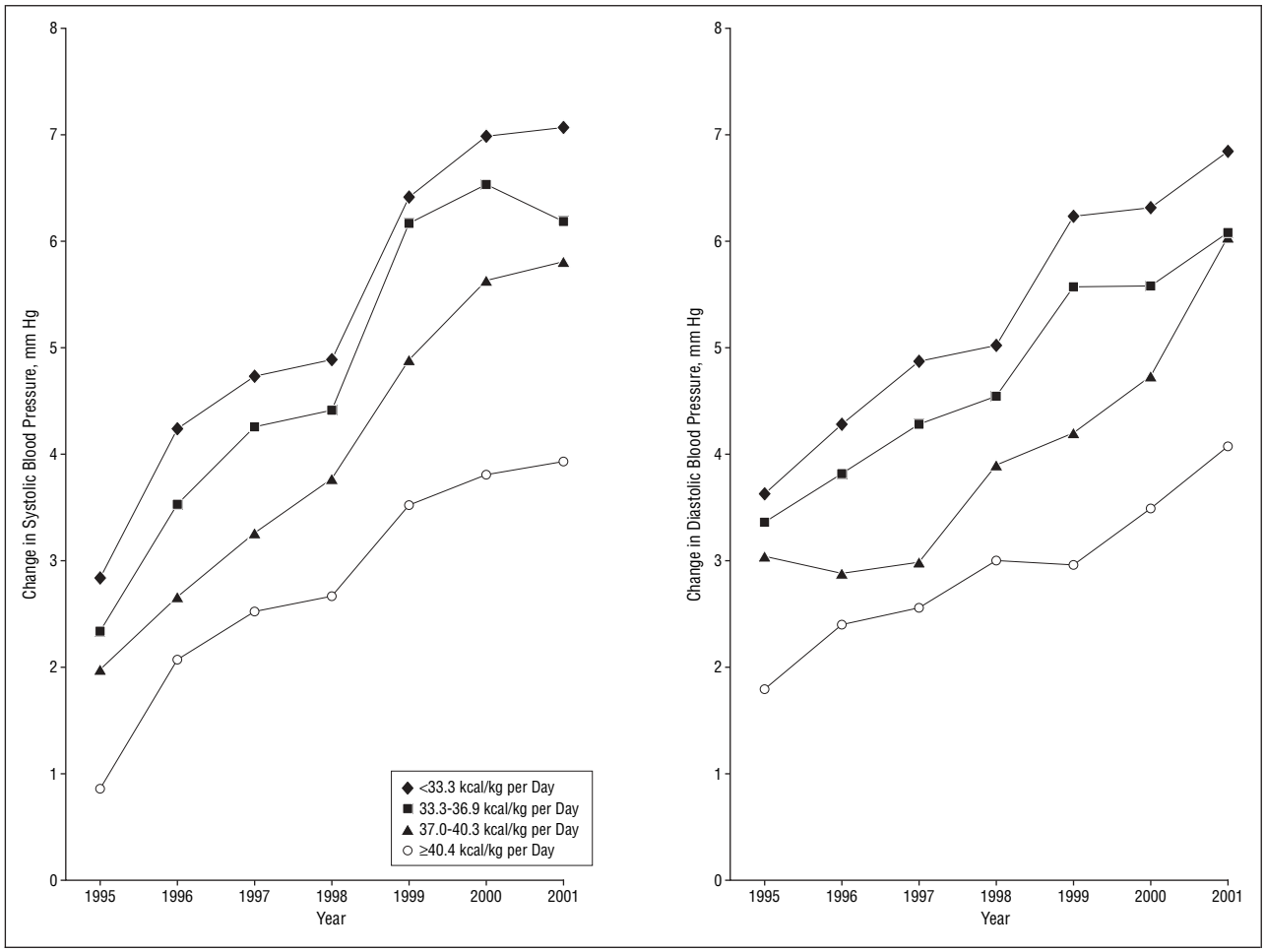

Figure. Mean blood pressure changes over a 7-year follow-up period according to daily life energy expenditure, adjusted for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise at study entry, and change in body mass index during the follow-up period.

Table 3. Risk of Developing Hypertension During 7 Years of Follow-up by Quartile of Habitual Physical Energy Expenditure

	Habitual Physical Energy Expenditure, kcal/kg per Day				
Variable	**<33.3**	**33.3-36.9**	**37.0-40.3**	**≥40.4**	***P* for Trend**
Cases/person-years	350/2632	293/3005	248/3144	188/3518	
Rate per 1000 person-years	133.0	97.5	78.9	53.4	
Age-adjusted RR (95% CI)	1.00 (Referent)	0.76 (0.65-0.89)	0.64 (0.54-0.75)	0.44 (0.37-0.53)	<.001
Multivariate-adjusted RR (95% CI)*	1.00 (Referent)	0.77 (0.66-0.90)	0.64 (0.54-076)	0.45 (0.37-0.53)	<.001
Multivariate-adjusted RR (95% CI)†	1.00 (Referent)	0.84 (0.72-0.98)	0.75 (0.63-0.88)	0.54 (0.45-0.64)	<.001

Abbreviations: CI, confidence interval; RR, relative risk.

*Adjusted for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise at study, entry and change in body mass index during the follow-up period.

†Additional adjustment for systolic blood pressure at study entry.

crease in daily life energy expenditure. Alcohol consumption and cigarette smoking did not differ significantly across quartiles of daily life energy expenditure.

The **Figure** shows mean blood pressure changes over a 7-year follow-up according to daily life energy expenditure. With the adjustment for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise at entry, and change in BMI during the follow-up period, changes in both SBP and DBP significantly differed among the 4 groups of daily life energy expenditure in each follow-up year ($P<.05$ for all) and decreased with an increase in daily life energy expenditure. Changes in both SBP and DBP increased progressively among each group of daily life energy expenditure with an increase in age (P for trend, $<.001$ for all).

During the 7 years of follow-up representing 12 300 person-years, 1079 men developed hypertension (**Table 3**). After adjustment for age, family history of

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Table 4. Risk of Developing Hypertension During 7 Years of Follow-up by Quartile of Habitual Physical Energy Expenditure Within Subgroups*

Risk Factor	Cases/ Person-Years	Rates per 1000 Person-Years	Habitual Physical Energy Expenditure, kcal/kg per Day				*P* for Trend	*P* for Interaction
			<33.3	33.3-36.9	37.0-40.3	≥40.4		
Age (median, 46.4 y)								
<Median	515/6502	79.2	1.00 (Referent)	0.83 (0.66-1.04)	0.72 (0.56-0.91)	0.45 (0.35-0.59)	<.001	.11
≥Median	564/5798	97.3	1.00 (Referent)	0.85 (0.68-1.05)	0.77 (0.61-0.97)	0.63 (0.49-0.81)	<.001	
Family history of hypertension								
No	689/8837	78.0	1.00 (Referent)	0.86 (0.70-1.04)	0.73 (0.59-0.90)	0.58 (0.46-0.72)	<.001	.47
Yes	390/3463	112.6	1.00 (Referent)	0.84 (0.65-1.09)	0.79 (0.60-1.03)	0.46 (0.33-0.63)	<.001	
Current alcohol intake								
No	129/1906	67.7	1.00 (Referent)	0.87 (0.56-1.34)	0.83 (0.52-1.32)	0.39 (0.22-0.71)	.003	.40
Yes	950/10 394	91.4	1.00 (Referent)	0.84 (0.71-0.99)	0.74 (0.62-0.88)	0.56 (0.46-0.67)	<.001	
Current smoking								
No	541/5826	92.9	1.00 (Referent)	0.89 (0.72-1.11)	0.74 (0.57-0.94)	0.56 (0.43-0.73)	<.001	.64
Yes	538/6474	83.1	1.00 (Referent)	0.77 (0.62-0.97)	0.74 (0.59-0.93)	0.50 (0.39-0.65)	<.001	
BMI (median, 23.1)								
<Median	449/6601	68.0	1.00 (Referent)	0.70 (0.48-1.03)	0.64 (0.44-0.92)	0.47 (0.32-0.67)	<.001	.85
≥Median	630/5699	110.5	1.00 (Referent)	0.88 (0.73-1.05)	0.81 (0.64-1.03)	0.60 (0.42-0.86)	.002	
Regular physical exercise								
Hardly ever	520/5812	89.5	1.00 (Referent)	0.71 (0.57-0.88)	0.64 (0.50-0.82)	0.46 (036-0.60)	<.001	.30
At least once a week	559/6488	86.2	1.00 (Referent)	1.03 (0.82-1.28)	0.87 (0.69-1.10)	0.62 (0.48-0.80)	<.001	

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

*Unless otherwise indicated, values are expressed as the relative risk (95% confidence interval). Relative risks were adjusted for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise and systolic blood pressure at study, and change in BMI during the follow-up period.

hypertension, alcohol consumption, cigarette smoking, regular physical exercise, and SBP at entry and change in BMI during the follow-up period, the relative risks for hypertension across quartiles of daily life energy expenditure were 1.00, 0.84, 0.75, and 0.54 ($P<.001$ for trend).

Analyses stratified by age, family history of hypertension, alcohol use, cigarette smoking, BMI, and regular physical exercise showed consistent associations between daily life energy expenditure and risk of hypertension (**Table 4**). The effect of daily life energy expenditure seemed to be smaller in older men than in younger men, and, to the contrary, the beneficial effect of daily life energy expenditure on leaner men and men who hardly ever exercised was somewhat larger than in obese men and men who exercised at least once a week. However, results of tests for interaction between daily life energy expenditure and these risk factors in terms of developing hypertension were not statistically significant.

To examine whether blood pressure at entry affected the association between daily energy expenditure and the risk of developing hypertension, we stratified subjects according to blood pressure level into low normal, normal, and high normal (**Table 5**). Among men with low-normal blood pressure, the multivariate-adjusted relative risk of hypertension across quartiles of daily life energy expenditure were 1.00, 0.70, 0.55, and 0.43 ($P<.001$ for trend). The corresponding results were 1.00, 0.89, 0.69, and 0.50 for men with normal blood pressure ($P<.001$ for trend), and 1.00, 0.86, 0.88, and 0.60 for men with high-normal blood pressure ($P=.001$ for trend). The interaction between daily life energy expenditure and blood pressure level in terms of developing hypertension was significant ($P=.04$).

COMMENT

Our results showed that the rate of rise in both SBP and DBP in each follow-up year decreased with higher levels of daily life energy expenditure and that the risk of developing hypertension decreased in a dose-dependent manner with higher daily life activity level. Analyses stratified by the presence or absence of a risk factor (ie, age, family history of hypertension, alcohol intake, cigarette smoking, BMI, and regular physical exercise) showed the negative association of daily life activity with the risk of developing hypertension for men at both low and high risk of hypertension. This tendency was also observed among men in all 3 categories of normotension (low normal, normal, and high normal). Provided that our findings represent a causal relationship between increased daily life activity and the reduced risk of developing hypertension, daily life activity should be considered an important measure for the prevention of hypertension among men at either low or high risk of hypertension. However, the beneficial effect of daily life activity decreased with an increase in baseline blood pressure. Baseline blood pressure had a strong impact on the risk of developing hypertension in this population (incidence of hypertension among men in the lowest quartile of daily energy expenditure: 60.1, 120.0, and 226.3 per 1000 person-years for men with low-normal, normal, and high-normal blood pressure, respectively). Thus, the effect of daily life activity on the development of hypertension may be obscured by higher baseline blood pressure.

Our results are consistent with the concept that greater physical activity substantially reduces the risk of developing hypertension.[9-14] Although the mechanism of how

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Table 5. Risk of Developing Hypertension During 7 Years of Follow-up by Blood Pressure Level and Quartile of Habitual Physical Energy Expenditure

Blood Pressure Level	Habitual Physical Energy Expenditure, kcal/kg per Day				*P* for Trend
	<33.3	33.3-36.9	37.0-40.3	≥40.4	
Low normal					
Cases/person-years	52/865	48/1233	44/1462	41/1682	
Incidence density, per 1000 person-years	60.1	38.9	30.1	24.4	
Age-adjusted RR (95% CI)	1.00 (Referent)	0.68 (0.46-1.01)	0.53 (0.36-0.80)	0.43 (0.28-0.65)	<.001
Multivariate-adjusted RR (95% CI)*	1.00 (Referent)	0.70 (0.47-1.05)	0.55 (0.37-0.83)	0.43 (0.28-0.65)	<.001
Normal					
Cases/person-years	115/958	105/1033	84/1059	68/1180	
Incidence density, per 1000 person-years	120.0	101.7	79.4	57.6	
Age-adjusted RR (95% CI)	1.00 (Referent)	0.86 (0.66-1.11)	0.68 (0.51-0.90)	0.50 (0.37-0.68)	<.001
Multivariate-adjusted RR (95% CI)*	1.00 (Referent)	0.89 (0.68-1.16)	0.69 (0.52-0.91)	0.50 (0.37-0.68)	<.001
High normal					
Cases/persons-years	183/809	140/740	120/624	79/656	
Incidence density, per 1000 person-years	226.3	189.3	192.3	120.4	
Age-adjusted RR (95% CI)	1.00 (Referent)	0.87 (0.69-1.08)	0.88 (0.70-1.11)	0.59 (0.45-0.77)	<.001
Multivariate-adjusted RR (95% CI)*	1.00 (Referent)	0.86 (0.69-1.07)	0.88 (0.69-1.11)	0.60 (0.46-0.78)	.001

Abbreviations: CI, confidence interval; RR, relative risk.
*Adjusted for age, family history of hypertension, alcohol consumption, cigarette smoking, regular physical exercise and systolic blood pressure at study entry, and change in body mass index during the follow-up period.

an increase in daily life activity reduces the risk for hypertension remains unclear, the finding that an increase in daily life activity is associated with a lower risk of hypertension is biologically plausible. It has been suggested that the effects of physical activity on hypertension may be mediated in part by increased insulin action, characterized by low insulin levels.[25,26] An etiologic relation between hyperinsulinemia and hypertension has been inferred from studies showing a direct effect of insulin on renal sodium absorption,[27] sympathetic nervous system activity,[28] and vascular smooth muscle growth.[29] However, the exact mechanism influencing the interaction between hypertension and the other factors the insulin resistance syndrome comprises is not well defined.

Our study had several limitations. First, a 1-day activity record during an ordinary weekday was used to estimate overall energy expenditure. This may have led to the misclassification of exposure measures and may have resulted in a biased estimate of the association between daily life activity and risk of hypertension. In this study, there was a clear dose-response relation between daily life energy expenditure and biological markers of physical activity such as high-density lipoprotein cholesterol level (Spearman correlation coefficient [r] = 0.301; $P<.001$) and triglyceride level ($r=-0.319$; $P<.001$). In addition, an employee in Japan often stays at the same job until retirement. All the participants in this study were white-collar workers not working in a shift system, and most were professionals. Thus, physical activity in daily life may be a consistent and reliable indicator of physical activity status throughout adult life.

Second, the variability of blood pressure measurements is widely recognized,[1,30] which makes it difficult to establish both accurate measurement of an individual's blood pressure and of the subsequent incidence of hypertension in epidemiological studies that rely on a limited number of blood pressure readings. We are fully aware of the limitations caused by our dependence on casual blood pressure readings to define persons at risk and those developing elevated blood pressure levels. However, it has been argued that subsequent blood pressure elevation or cardiovascular disease can be predicted equally well by casual blood pressure as by near-basal blood pressure,[31] so casual readings may also be useful for the definition and study of the incidence of hypertension.

Third, only selected variables were assessed as confounding factors for hypertension incidence. Several previous studies have identified resting heart rate or salt consumption, particularly when coupled with a low intake of potassium, as predictors of hypertension,[32-34] so further investigation is needed to clarify the causal relation between daily life activity and the development of hypertension.

Finally, bias in case finding could have occurred. However, because all incident cases were detected during the periodic annual screening in our study, such a bias is unlikely to have been a factor. Furthermore, all subjects were registered white-collar workers of a single company and thus are not representative of the general Japanese population. The relative homogeneity of the study population may enhance the study's internal validity. That is, the uniform educational background and socioeconomic status of the men in this population make it unlikely that the variables represent confounding factors.

Despite these potential limitations, our findings demonstrate that daily life activity is inversely associated with the risk of developing hypertension and that the risk of developing hypertension is more pronounced among physically inactive men with a high-normal blood pressure. To prevent hypertension, clinicians should focus their attention on the patients' physical activity in daily life, and individuals who are physically inactive in daily life and are at the higher end of the normal blood pressure spectrum should be followed up carefully.

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Accepted for Publication: July 27, 2004.
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Funding/Support: This study was supported in part by grants-in-aid from the Japan Arteriosclerosis Prevention Fund, Tokyo, Japan, and the Smoking Research Foundation, Tokyo.

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