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Beneficial effect of physical activity on blood pressure and blood glucose among Japanese male workers

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ABSTRACT

Aims: To examine the appropriate type and frequency of physical activity for the beneficial effect on hypertension and hyperglycemia.
Methods: The incidence of hypertension and hyperglycemia was assessed using the results of annual physical checkups over 4 years for 5843 male employees aged 18–57 years old. Associations of different types of physical activity with the incidence of these two risk factors were examined with Cox proportional-hazard models.
Results: There was a progressive reduction in the hazards ratios of hypertension with increasing total daily activity (hazards ratio of 0.65 (95% CI, 0.45–0.93) in subjects who walked >8000 steps/day vs. <4000 steps/day). Subjects who exercised >3 times/week also showed a significantly lower risk (0.35; 0.13–0.96) of developing hypertension vs. those who exercised <3 times/week. The only physical activity factor associated with a lower incidence of hyperglycemia was weekend (Saturday and Sunday) physical activity (0.66; 0.43–0.99, very active vs. sedentary on weekends).
Conclusion: Increasing daily and leisure time physical activities had a beneficial effect on hypertension independent from physical activity at weekend, while only doing physical activity on weekends affects an elevation of blood glucose independent of daily and leisure time physical activity.

1. Introduction

Hypertension and type-2 diabetes are important public health challenges worldwide because of their high prevalence. A recent Japanese national survey showed that 25.8% and 14.0% of men aged 50–59 had hypertension [1] and type-2 diabetes [2], respectively. These diseases are also known as strong risk factors for cardiac and cerebrovascular diseases [3,4], which are reported to be the second and third most frequent causes of death in Japan [5]. Thus, hypertension and type-2 diabetes are very serious problems not only for their alarming prevalence but also for the strong risk they pose of more life-threatening diseases.

Physical activity is known to be an effective tool for the primary prevention of hypertension and type-2 diabetes [3,4]. However, evidence for the appropriate amount, type, and frequency (including interval) of physical activity is limited, especially for Japanese or Asian populations. A study following Harvard male alumni reported that vigorous and/or moderately vigorous sports may reduce the risk of hypertension, but walking and light sports did not alter that risk [6]. A population-based prospective study showed that leisure-time

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physical activity (primarily cycling and walking) reduced the risk of hypertension in middle-aged white men [7].

A study focused on the prevention of type-2 diabetes found that increasing physical activities was effective in preventing the disease [8]. Physical activity was found to be a promising approach to primary prevention of type-2 diabetes [9]. Similar results were obtained in another investigation using a physical activity index [10].

Recent Japanese studies from the same cohort indicated the possibility that the appropriate physical activity to prevent hypertension and type-2 diabetes was different [11,12]. A longer than 20-min walk to work, or regular physical activity at least once a week during leisure time (e.g., jogging) reportedly reduced the risk of hypertension [11]. Moreover, men who engaged in regular physical activity at least once a week had a hazard ratio of type-2 diabetes of 0.75 while those engaging in vigorous activity at least once a week on a weekend had a risk of 0.55 compared with subjects not participating in any physical activity [12]. Thus, though daily physical activity markedly reduced the risk of hypertension, no similar effect was reported in the case of type-2 diabetes. It is therefore very important to clarify the appropriate type, amount, and frequency (or interval) of physical activities recommended for the prevention of hypertension and type-2 diabetes.

The purpose of this study was to clarify the effect of daily, occupational, and leisure-time physical activity and physical activity at weekend on the incidence of hypertension and hyperglycemia among Japanese male workers, and provide substantial evidence for the recommendation of physical activity.

2. Subjects and methods

2.1. *Subjects*

Subjects of the present study were male employees of a bearing manufacturer with its head office, 36 branches, and 12 factories in Japan. In 1994, 5843 male employees of that company had regular physical checkups. Among them, 61 with a history of ischemic heart disease, cancer, or a cerebrovascular accident were excluded from the study. We also excluded 1058 who worked alternate day and night shifts, since they showed a higher prevalence of comorbidity than daytime workers as well as an additional 1845 who already had an above normal blood pressure or fasting blood glucose level at baseline. This left 2879 qualified subjects, all of whom continued to undergo annual regular physical checkups and were followed until 1998. This study was approved by the Ethics Committee of the National Institute of Health and Nutrition, Japan.

2.2. *Criteria for hypertension and hyperglycemia*

Hypertension and hyperglycemia were diagnosed at the annual physical checkup. Hypertension was defined using the criteria of JNC-7 (systolic blood pressure > 140 and/or diastolic blood pressure > 90 mmHg) [3], or by the use of antihypertensive medication. Hyperglycemia was defined according to the criteria of the Japan Diabetes Association (fasting blood glucose > 126 mg/dl) [13], or by taking the appropriate medication for type-2 diabetes.

2.3. *Physical checkup*

The annual physical checkup consisted of physical examinations, anthropometric measurements (height and body weight), and measurements of blood pressure and fasting plasma glucose. Body mass index (BMI) was calculated by weight in kilograms divided by the height squared in meters. Blood pressure at rest was obtained in duplicate after at least a 5-min rest using a sphygmomanometer. Venous blood was drawn after an overnight fast, and analyzed at a central laboratory (Mitsubishi Kagaku Bio-Clinical Laboratories, Tokyo, Japan). Physicians and nurses employed by the company conducted all standardized measurements.

2.4. *Questionnaire*

Each subject filled out a questionnaire on personal medical history, parental history, and health-related behaviors such as physical activity, smoking, and daily alcohol consumption. The specific questions about leisure-time physical activity both on weekdays and weekends asked the frequency, duration, and intensity of regular physical activity. The number of days of more than 30 min of moderate to vigorous physical activity was categorized as none, one to three times per week, and more than three times per week. Daily activity was queried in terms of average walking steps per day. Subjects were able to accurately answer the question about daily walking steps because more than 90% of the employees had been earlier provided with pedometers by the company's health insurance association. The question for physical activity on the weekend was as follows: ''how do you spend your weekend?'' and scored as very active (doing more than one hour of moderate to vigorous physical activity on both days), active (doing less than one hour of moderate to vigorous physical activity on both days), occasional (doing moderate to vigorous physical activity on one day and staying sedentary on the other day), less active (almost sedentary with some light activity on both days), and sedentary (completely sedentary with sitting or lying down on both days). They were then classified into very active (very active and active), occasional, and sedentary (less active and sedentary). The question about occupational physical activity was ''how much do you move during your work?'', and answers were mostly manual work, somewhat manual work, light standing and moving, light standing and little moving, and stationary. Answers were classified into manual work (mostly manual work and somewhat manual work), light standing or moving (light standing and moving, and light standing and little moving), and stationary.

2.5. *Statistical analysis*

Person-years for each man for hypertension and hyperglycemia were estimated from the day of his first regular physical checkup in 1994 (baseline) up to the day when the corresponding disease was first diagnosed, his retirement, or until 1998, whichever came first. Incidence rates were calculated by

dividing the number of cases by person-years in each category. Hazards ratios were calculated by multivariate Cox proportional hazard regression analysis in each category adjusted for age. Future multivariate Cox proportional hazard regression analysis was used to adjust simultaneously for age, BMI, smoking status, alcohol intake, parental history, and baseline value of blood pressure or blood glucose. Furthermore, additional future analysis was conducted using the above variables together with three kinds of physical activity (daily, leisure time, and weekend). The changes in blood pressure or fasting blood glucose between 1994 and 1998 were compared by general regression model adjusted for age, BMI, smoking status, alcohol intake, parental history, and baseline levels of blood pressure or glucose.

Table 1 – Baseline characteristics of subjects.

	Mean + SD	Range
Age (years)	36 + 10	18–57
Body weight (kg)	63.1 + 8.4	42–105
Height (cm)	169 + 6	147–190
Body mass index (kg/m^2)	22.1 + 2.6	14.9–36.5
Systolic blood pressure (mmHg)	115 + 9	80–129
Diastolic blood pressure (mmHg)	68 + 9	32–84
Fasting blood glucose (mg/dl)	88 + 9	50–109
Current smoker (%)	63.3	
Current drinker (%)	70.9	
Habitual physical exercise (%)	40.0	

$n = 2879$.

3. Results

Table 1 illustrates the baseline characteristics of the study population (2879 men) in 1994. During the 4-year follow-up period, newly diagnosed cases numbered 252 (23.6 per 1000 person-years) for hypertension and 119 (11.0 per 1000 person-years) for hyperglycemia. During 4 years, only 27.7% of the subjects did not change their daily physical activity; 43.4% decreased and 27.7% increased their daily physical activity. When the changes in daily physical activity were compared among the groups by the daily physical activity level of 1994, 72.9% of the subjects who walked more than 8000 steps per day reduced their daily physical activity. Among the subjects who walked between 4000 and 8000 steps per day in 1994, 36.3% decreased and 34.5% increased their walking steps; and 56.6% of the subjects who walked less than 4000 steps per day in 1994 increased their walking steps. According to the frequency of leisure-time physical activity, 43.6% increased and 18.0% decreased their regular physical activity. Among the subjects who participated more than three times per week in leisure-time physical activity, 49.5% decreased the frequency. Among the subjects who participated in regular physical activity one to three times per week, 35.7% increased and 47.7% decreased the frequency, and 50.6% of the subjects who participated less than once a week started physical activity more than once a week.

Table 2 shows the hazards ratio of developing essential hypertension according to each physical activity. There was a significant and progressive reduction in the hazards ratio of hypertension with increasing daily activity ($p = 0.013$ for trend), measured in terms of walking-steps per day. The

Table 2 – Hazard ratio for developing essential hypertension according to physical activity.

	No. of cases	Person-years	Cases of hypertension	Rate per 1000 person-years	Hazard ratio			
					Age-adjusted (95% CI)	*p* value for trend	Multivariate (95% CI)	*p* value for trend
Daily activity (steps per day)								
≦4000	549	2015	60	29.8	1.00 (reference)		1.00 (reference)	
>4000 to <8000	1355	5019	114	22.7	0.75 (0.55–1.02)		0.64 (0.46–0.91)	
≧8000	975	3658	78	21.3	0.64 (0.46–0.90)	0.01	0.57 (0.39–0.82)	0.00
Occupational physical activity								
Stationary (sitting)	864	3168	59	18.6	1.00 (reference)		1.00 (reference)	
Light standing or moving	534	1996	48	24.0	0.89 (0.63–1.27)		0.89 (0.61–1.30)	
Manual work	1481	5528	115	20.8	0.79 (0.59–1.05)	0.08	0.75 (0.55–1.02)	0.05
Physical activity on weekend								
Sedentary	304	1117	28	25.1	1.00 (reference)		1.00 (reference)	
Occasional	1658	6157	139	22.6	0.85 (0.57–1.28)		0.76 (0.49–1.19)	
Very active	917	3418	85	24.9	0.83 (0.54–1.28)	0.49	0.75 (0.47–1.19)	0.26
Leisure-time physical activity								
Frequency (times per week)								
0	1794	6652	160	24.1	1.00 (reference)		1.00 (reference)	
1–3	965	3788	88	23.2	1.16 (0.89–1.51)		1.19 (0.91–1.55)	
>3	120	452	4	8.8	0.35 (0.13–0.95)	0.29	0.37 (0.14–1.00)	0.37
Exercise intensity								
None	1794	6652	160	24.1	1.00 (reference)		1.00 (reference)	
Moderate	610	2264	58	25.6	1.07 (0.79–1.44)		1.12 (0.83–1.52)	
Vigorous	475	1776	34	19.1	1.03 (0.70–1.50)	0.83	1.01 (0.69–1.48)	0.87

Table 3 – Hazard ratio for developing type-2 diabetes mellitus according to physical activity.

	No. of cases	Person-years	Cases of diabetes mellitus	Rate per 1000 person-years	Hazard ratio			
					Age-adjusted (95% CI)	*p* value for trend	Multivariate (95% CI)	*p* value for trend
Daily activity (steps per day)								
≦4000	549	2051	26	12.7	1.00 (reference)		1.00 (reference)	
>4000 to <8000	1355	5110	52	10.2	0.76 (0.48–1.22)		0.80 (0.50–1.28)	
≧8000	975	3679	41	11.1	0.73 (0.45–1.20)	0.26	0.76 (0.46–1.24)	0.31
Occupational physical activity								
Stationary (sitting)	864	3235	36	11.1	1.00 (reference)		1.00 (reference)	
Light standing or moving	534	2023	19	9.4	0.94 (0.53–1.66)		0.99 (0.57–1.73)	
Manual work	1481	5581	64	11.5	1.17 (0.77–1.78)	0.40	1.21 (0.80–1.82)	0.35
Physical activity on weekend								
Sedentary	304	1139	15	13.2	1.00 (reference)		1.00 (reference)	
Occasional	1658	6252	63	10.1	0.72 (0.49–1.06)		0.72 (0.49–1.07)	
Very active	917	3447	40	11.6	0.62 (0.41–0.94)	0.04	0.66 (0.43–0.99)	0.09
Leisure-time physical activity								
Frequency (times per week)								
0	1794	6737	81	12.0	1.00 (reference)		1.00 (reference)	
1–3	965	3647	34	9.3	0.96 (0.64–1.44)		0.99 (0.66–1.48)	
>3	120	1727	19	11.0	0.70 (0.26–1.92)	0.52	0.74 (0.27–2.02)	0.62
Exercise intensity								
None	1794	6737	81	12.0	1.00 (reference)		1.00 (reference)	
Moderate	610	2297	27	11.8	0.99 (0.64–1.52)		1.02 (0.66–1.58)	
Vigorous	475	1806	11	6.1	0.80 (0.42–1.51)	0.51	0.82 (0.43–1.55)	0.61

adjusted hazards ratio was 0.57 (95% CI, 0.39–0.82) for men who walked more than 8000 steps per day compared with those who walked less than 4000. There were also progressive reductions in the hazards ratio with increasing occupational physical activity ($p = 0.05$ for trend). On the other hand, activity on the weekend did not significantly affect the incidence of hypertension. Men who performed regular physical exercise more than three times per week showed a lower risk (0.37, 95% CI, 0.14–1.00) compared with those who exercised three times or less. However, the trend analysis for frequency of leisure-time physical activity showed no statistical significance, nor did the intensity. When the change of systolic and diastolic blood pressure between 1994 and 1998 was compared, subjects doing manual work showed significantly smaller increases in systolic blood pressure compared to subjects doing stationary work. Subjects who walked more than 8000 steps per day and subjects who participated in regular physical exercise more than three times per week also showed smaller increases than more sedentary subjects.

Table 3 indicates the hazards ratio of developing hyperglycemia according to each physical activity. Although daily activity was associated with lower hazards ratios, the differences did not reach statistical significance. Hazard ratios for men who walked between 4000 and 8000 and over 8000 steps/day were not significantly different from less than 4000 steps per day. Although there was no significant association between occupational physical activity and the risk of developing hyperglycemia, we found a progressive reduction in that risk with increasing physical activity on weekends ($p = 0.09$ for trend); subjects who were very active on weekends demonstrated a significantly lower hazards ratio (0.66, 95% CI, 0.43–0.99) compared to the sedentary groups. Neither the frequency nor the intensity of leisure-time physical activity was associated with the incidence of hyperglycemia. The changes of fasting blood glucose between 1994 and 1998 were also compared among each physical activity. However, there was no significant difference in the change of blood glucose according to the level of physical activity.

In order to examine the independent beneficial effect of each activity on hypertension and hyperglycemia, another multiple model was created, including three significantly relevant physical activities (daily activity, physical activity on weekends, and frequency of leisure-time physical activity). Table 4 indicates the independent effect of each physical activity on hypertension and hyperglycemia. The hazards ratio of hypertension was significantly reduced in subjects engaging in more than 4000 steps/day of daily activity and more than three times/week of leisure-time physical activity independent of the other two physical activities. On the other hand, the hazards ratio of hyperglycemia was significantly lowered only by physical activity on weekends independent of daily and leisure-time physical activity.

4. Discussion

The present study among Japanese male workers showed that weekday daily activity was associated with a decreased risk for hypertension, while greater physical activity on weekends decreased the risk of hyperglycemia. This result was significant even after adjustments for age, BMI, smoking status, alcohol intake, parental history, and baseline value of blood pressure or blood glucose. Furthermore, the effects of daily activity and leisure-time physical activity on the risk for hypertension were independent of daily physical activity. The effect of weekend physical activity on the risk of hypergly-

Table 4 – Independent effect of each physical activity on the morbidity for hypertension and type-2 diabetes mellitus.

	No. of cases	Hypertension		Diabetes mellitus	
		Hazard ratio	*p* value	Hazard ratio	*p* value
Daily activity (steps per day)					
<4000	549	1.00 (reference)		1.00 (reference)	
>4000	2,330	0.66 (0.49–0.88)	0.01	0.94 (0.68–1.29)	0.68
Physical activity on weekend					
Sedentary	304	1.00 (reference)		1.00 (reference)	
Active	2,575	0.84 (0.56–1.26)	0.40	0.74 (0.50–0.99)	0.05
Leisure-time physical activity					
<3 times/week	2,759	1.00 (reference)		1.00 (reference)	
>3 times/week	120	0.38 (0.14–0.99)	0.05	1.12 (0.61–2.06)	0.72

Hazard ratio was adjusted for age, BMI, smoking status, alcohol intake, baseline value (systolic blood pressure or blood glucose), and family history. Daily activity, physical activity on weekend, and leisure-time physical activity were incorporated in one model.

cemia was independent of daily activity and leisure-time physical activity.

We collected data on regular physical exercise, daily activity, occupational activity, and activity on weekends, and all subjects were followed using annual health checkups. The resulting physical activity data enabled us to separately compare the effects of weekday and weekend activity. Use of the regular annual checkup allowed us to use the same criteria when assessing the incidence of hypertension and hyperglycemia in all subjects.

The incidence rate of hypertension in this study was 23.6 per 1000 person-years, whereas in previous studies it varied from 6.4 to 142 per 1000 person-years [6,7,11,14]. This discrepancy arises from differences in the criteria for hypertension (JNC-7 or WHO), especially the age of subjects at the time, and the time of the data collection. The incidence rate of hyperglycemia in this study was 11.0 per 1000 person-years, which was somewhat higher compared to that in previous data for type-2 diabetes (less than 5 per 1000 person-years) [8,16,17]. The discrepancy here arose mainly from the difference in criteria. Most studies used questionnaires eliciting the use of diabetic medication or clinically diagnosed type-2 diabetes. The present study only examined the incidence of hyperglycemia or taking medication for type-2 diabetes, which led to reporting a relatively higher incidence. Two other studies on Japanese using blood tests showed higher incidences of 7.4 and 25.6 per 1000 person-years [12,15].

Subjects engaging in greater physical activity daily or during leisure time showed a lower risk of hypertension, whereas weekend activity had no effect on the risk. In addition, subjects doing manual work showed smaller increases in systolic blood pressure during the observation period. The preventive effect of leisure-time activity corresponds to previous studies [6,7,11,14,16]. However, the intensity of leisure-time physical activity was not associated with the risk of hypertension. A high frequency of moderate physical activity such as daily walking reduces the risk of hypertension. In addition, a higher amount of physical activity in their occupation, which means a higher physical activity five days a week, prevented an increase in blood pressure. It was also shown that subjects regularly taking more than a 21-min walk to work decreased their risk of hypertension [11]. Moreover, a recent study suggested that increasing the habitual total daily energy assessed by one-day activity records reduced the risk of hypertension [16]. This is in accordance with many reports that recommend common activity (such as brisk walking, cycling or climbing stairs) on most days of the week to prevent hypertension [16–18].

On the other hand, only subjects physically active on weekends showed a reduced risk of hyperglycemia. The present result supports the recommendation by the American Diabetes Association that proposes not more than two consecutive days without aerobic physical activity [19,20] because staying sedentary on weekends means staying inactive during two consecutive days (Saturday and Sunday). The present questionnaire on leisure-time physical activity did not separate weekdays and weekends. However, the multiple regression analysis suggested that physical activity on weekends affects the incidence of hyperglycemia independently from daily activity and frequency of leisure-time physical activity (Table 4). Most studies have suggested that subjects with a greater total amount of leisure-time physical activity per week had a lower risk of type-2 diabetes [8,10,12,21–25]. On the other hand, a recent Japanese report showed that men who engaged in vigorous activity at least once a week on weekends had a strikingly low risk of 0.55 compared with those who avoided vigorous activity [12], a result with which the present study concurs. We considered that even if subjects did not engage in much leisure-time physical activity, they would not be completely sedentary on weekdays because they were engaged in their work. Then only staying completely sedentary on weekends may affect the glucose metabolism. As for inactivity, two studies which examined the effect of sedentary behavior on the risk of type-2 diabetes suggested that sedentary behavior such as watching television was associated with an elevated risk [26,27].

The present study demonstrates the possibility that physical activity produces different effects on blood pressure and blood glucose based on epidemiological data. Increasing daily and leisure-time physical activities was an essential factor in preventing hypertension, and daily occupational physical activity prevented an increase in blood pressure. However, only doing physical activity on weekends had a beneficial effect on blood glucose. The reason for this is thought to be the differences in the time course of the appearance or disappearance of the effects of exercise

between blood pressure and blood glucose. An earlier study indicated that exercise reduced blood pressure immediately after a training session, and blood pressure remained low for one to two weeks [28]. Steadily increasing weekday physical activity may contribute to reducing blood pressure and maintaining it at a low level even for subjects who are inactive on the weekend. In contrast, it was suggested that the metabolic clearance rate for insulin increased gradually during one year of a jogging program [29]. A study of trained athletes indicated that insulin sensitivity decreased 60 h after the last bout of training [30]. It is likely that staying sedentary on weekends (Saturday and Sunday) adversely affects glucose metabolism to the extent that it fails to recover sufficiently during the remaining five days of the week because the present study suggests that physical activity on weekends affected hyperglycemia independently from daily physical activity and leisure-time physical activity. The American Diabetes Association also recommended that there should not be more than two consecutive days without aerobic physical activity because the duration of the increased insulin sensitivity occurring by a single bout of exercise was generally not more than 72 h [19].

Our study has some potential limitations. First, since all subjects were men and employees of the same company, the present results may not be representative of the general population. However, since the subjects resided in many regions of Japan and worked at a variety of occupations, our results are thought to adequately represent many men who work outside the home. Second, we could not include several confounding factors. For instance, though food intake is thought to greatly affect the incidence of both hypertension and hyperglycemia, we could not include a diet questionnaire at baseline. In addition, we queried only the frequency of alcohol consumption but not the amount consumed. A six-year longitudinal study suggested a dose-response relationship between alcohol intake and the incidence of hypertension [31]. Therefore, we recommend that a diet history and alcohol intake amount should be included in future studies. Third, the physical activity was assessed only by questionnaire. We could not use an objective measurement for physical activity like a pedometer or accelerometer. However, subjects were able to answer about their daily walking steps, because almost all subjects usually used pedometer. Fourth, we could not examine the effect of the changes in physical activity level during 1994–1998 on the risk of hypertension and hyperglycemia. We divided the subjects only by the physical activity level in 1994 because of their limited numbers, although more than 70% of the subjects increased or decreased their physical activity during 4 years.

This result suggests a beneficial effect of physical activity on hypertension and hyperglycemia. At the same time, our results also show the possibility that physical activity affects blood pressure and blood glucose differently according to the frequency or interval of physically active days.

Conflict of interest

The authors declare that there are no financial and personal relationships with other people or organizations that could inappropriately influence this study. None of the authors had any personal or financial conflicts of interest.

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