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Can leisure-time physical activity improve health checkup results? Evidence from Japanese occupational panel data

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Abstract: Objectives: We examined the extent to which changes in worker health, as measured by health checkup items, were associated with increased intensity of leisure-time physical activity (LTPA) after controlling for individual time-invariant attributes. **Methods:** We used panel data from two to four waves of a Japanese occupational cohort survey, focusing on 30,206 observations of 10,106 individuals (7,669 men and 2,437 women) aged 18-76 years. We estimated first-difference and mean-centered fixed effects models to examine how changes in 10 health checkup items were associated with changes in LTPA intensity. We considered four LTPA intensity levels (none, low, moderate, and vigorous), based on self-reported assessments. **Results:** For men, low-density lipoprotein cholesterol levels, glycated hemoglobin levels, body mass index, and waist circumference improved when LTPA intensity was increased even at a low level, whereas triglyceride, high-density lipoprotein cholesterol, and fasting blood glucose levels improved when LTPA intensity was increased to moderate or vigorous levels. Blood pressure (both systolic and diastolic) and total cholesterol levels were only modestly responsive to changes in LTPA intensity. For women, blood pressure (both systolic and diastolic) and waist circumference were negatively associated with LTPA intensity, whereas the other variables showed more modest effects. **Conclusions:** The results suggest that even low- to moderate-intensity LTPA can improve health checkup results; however, the lowest LTPA intensity associated with improvement in health depends on health-risk factors as well as gender.
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Introduction

It is widely known that leisure-time physical activity (LTPA) has a beneficial impact on worker health. Many cohort studies have reported that LTPA of moderate to vigorous intensity reduces risks of mortality[1-7], cardiovascular disease[8-10], hypertension[11-13], hyperglycemia[13,14], cholesterol[11,15], obesity[15-17], and other conditions. However, the associations between changes in the intensity of LTPA and health risk factors have been relatively understudied[17,18]. Moreover, few studies have explicitly compared associations among health risk factors using the same dataset.

Annual workplace health checkups are expected to provide useful information for investigation of the associations between changes in LTPA intensity and health risk factors[19]. Occupational panel surveys, which collect data regarding annual health checkup results and LTPA in separate waves, are expected to reliably and consistently capture their relatively short-term relationships. The findings from analyses based on such surveys are expected to complement those obtained from previous cohort studies, which have often focused on the relatively long-term effects of LTPA, particularly in terms of mortality[2-6].

A key challenge in examining the association between LTPA and health is addressing potential biases due to insufficient control for individual attributes that are likely to confound associations. These biases cannot be removed even if an individual's socioeconomic and sociodemographic factors are included as covariates in regression models because it is impossible to control for unobserved attributes. To circumvent this problem, some researchers have employed prospective cohort analyses, comparing LTPA at baseline, or its continuation, with health outcomes at follow-up[2-6,10,13,14,17,18]. Still, these analyses cannot fully control for individual time-invariant attributes, which are most likely to affect LTPA and health outcomes even at different timepoints.

To tackle these issues, we employed both first-difference and mean-centered fixed effects models[20]. By controlling for an individual's time-invariant attributes, both observable and unobservable, these models captured the unbiased association between changes in LTPA intensity and worker health.

Materials and Methods

Study sample

We used panel data from four survey waves of an occupational cohort study on social class and health in Japan (Japanese Study of Health, Occupation, and Psychosocial Factors Related Equity; J-HOPE). The first wave was conducted from October 2010 to December 2011; subsequent waves were conducted approximately one year following previous ones. Data were collected from annual worksite health checkups, which the Industrial Safety and Health Law obliges all Japanese employees to undergo[19]. Recruitment periods varied among study sites; the health checkups were conducted during a fixed month every year for all employees, which was in each employee's birth month.

The study population consisted of employees working for thirteen firms, three of which joined only the first three waves. The surveyed firms covered twelve industries, and the surveyed respondents were classified into nine occupation types. The original sample consisted of 10,753; 11,405; 10,977; and 6,553 respondents in the first, second, third, and fourth waves, respectively (response rates: 77.0%, 81.7%, 78.6%, and 67.0%, respectively). The original dataset included 39,683 observations of 14,140 individuals (10,550 men and 3,590 women) who joined at least one wave. The attrition rates were 18.3%, 13.2%, and 16.5% in the second, third, and fourth waves, respectively. The respondents were between 18 and 76 years of age (M=41.5, SD=10.3).

To assess the associations between changes in LTPA intensity levels and health checkup results, we first limited our analysis to respondents with both LTPA and health checkup results. This step reduced the number of observations to 35,169. Secondly, we excluded observations missing at least one of six covariates: age, household income, job type, hours worked per week, alcohol consumption, and smoking (explained further in Measures section). This step reduced the number of observations further to 34,063. Finally, we focused on individuals who had joined at least two consecutive waves in order to examine the association between changes in LTPA and health. As a result, we utilized 30,206 observations of 10,106 individuals (7,669 men and 2,437 women; 76.1% of the original sample observations, and 71.5% of the originally sampled individuals). Among these, 2,629, 4,736, and 2,741 joined four, three, and two waves, respectively.

The Ethics Committee of the Graduate School of Medicine/Faculty of Medicine at the University of Tokyo, Kitasato University School of Medicine/Hospital, and the University of Occupational and Environmental Health, Japan, reviewed and approved the study aims and procedures (No. 2772, B12-103, and 10-004, respectively). The analyses were conducted using the J-HOPE dataset as of 22 August 2014.

Measures

LTPA

J-HOPE asked respondents to report their LTPA on a four-point scale. Specifically, it asked them to choose one statement from the following that accurately described their LTPA: (1) "There is no exercise or sport that I do every week"; (2) "I do mild exercise (without breathlessness or heart palpitations) one or more times per week"; (3) "I do heavy exercise (with breathlessness, heart palpitation, or sweating for at least 20 min) once or twice a week"; and (4) "I do heavy exercise (with breathlessness, heart palpitation, or sweating for at least 20 min) three times or more times a week." We denoted these levels as "inactive" (Level 0), "low" (Level 1), "moderate" (Level 2), and "vigorous" (Level 3), respectively. It should be noted that this questionnaire could not eliminate the possibility of a combination of different LTPA levels (such as moderate exercise twice per week plus vigorous exercise once a week), necessitating caution when interpreting the association between LTPA intensity and health. The nationally recommended standard of LTPA is 60 minutes of heavy exercise per week[21], which lies somewhere between "moderate" and "vigorous" intensities in the present study. We constructed four binary variables that corresponded to four LTPA levels (Levels 0 to 3), and used those corresponding to Levels 1 to 3 to classify subjects, taking Level 0 as a reference.

Health checkup items

We considered 10 health checkup items: (1) systolic blood pressure; (2) diastolic blood pressure; (3) triglyceride level; (4) high-density lipoprotein (HDL) cholesterol level; (5) low-density lipoprotein (LDL) cholesterol level; (6) total cholesterol level; (7) fasting blood glucose level; (8) glycated hemoglobin (HbA1c) level; (9) body mass index (BMI); and (10) waist circumference. All these variables are known to be closely related to health risks. The data were collected at annual worksite health checkups.

Covariates

For covariates, we considered only time-variant variables, because observed time-invariant variables such as gender, educational attainment, and the firm for which the respondent worked were automatically removed from the fixed effects models (further explanation in Analytic Strategy section). We considered seven time-variant variables: (1) age, (2) household income, (3) job type, (4) hours worked per week, (5) alcohol consumption, and (6) smoking, all of which are assumed to confound the association between LTPA and health. We used (1), (2), and (4) as continuous variables and (3), (5), and (6) as categorical variables.

The survey asked respondents to choose from six household income brackets (≤2.99, 3-4.99, 5-7.99, 8-9.99, 10-14.99, and ≥15 million yen per year). To adjust for household size, we assumed midpoints of 1.5, 4, 6.5, 9, 12.5, and 18 million yen for each bracket respectively and divided by the square root of the number of household members. Jobs were categorized into nine types (managers, professionals, technicians, clerks, service and sales workers, craft and related trades workers, machine operators and assemblers, laborers, and others). We constructed binary variables for each job type. The survey asked the respondents to choose from five brackets (≤30, 31-40, 41-50, 51-60, or ≥61 hours) of hours worked per week. We assumed midpoints of 20, 35, 45, 55, and 65 hours for each bracket, respectively. The survey asked respondents to choose from "seldom," "sometimes," and "almost every day" for frequency of alcohol consumption, and we constructed binary variables for the latter two. Finally, we constructed a binary variable for current smoking. In addition to these individual attributes, we included indicator variables corresponding to the four waves in order to control for wave-specific factors.

Analytic strategy

We estimated regression models to examine the association between values of each health checkup item and intensity levels of LTPA, controlling for both time-variant and time-invariant factors for each respondent. The benchmark model for this analysis is given by (i = individual, t = wave)[22,23]:

$$y_{it} = \alpha_t + \beta_1 \text{Level } 1_{it} + \beta_2 \text{Level } 2_{it} + \beta_3 \text{Level } 3_{it} + X_{it}\gamma + Z_i\delta + \eta_i + \varepsilon_{it}.$$

Here, y_{it} is the value of the health checkup result. Level k_{it} (k=1, 2, 3) is a binary variable representing LTPA intensity, taking Level 0 (inactivity) as a reference. α_t is the time-varying intercept. X_{it} and Z_i are vectors of observed time-variant exposure variables (excluding LTPA) and observed time-invariant variables, respectively. η_i is a vector of unobserved time-invariant variables, ε_{it} is an error term, and γ and δ are coefficient vectors.

In the current study, the observed time-variant exposure variables (X_{it}) included six variables (age, household income, job type, hours worked per week, drinking, and smoking). The observed time-invariant variables (Z_i) included gender, educational background, and the firm for which the respondent was working. The unobserved time-invariant variables (η_i) potentially included personality traits and other inherent individual characteristics, chronic disease, and childhood experiences.

The value, sign, and statistical significance of the estimated coefficient on each LTPA (β_k) are of the greatest interest. The value of β_k indicates how the health checkup result at Level k differed from that at Level 0, and it can be interpreted as an expected change in the health checkup result with increased LTPA intensity from Level 0 to Level k. In this model setup, two things should be noted. Firstly, it is assumed that increases and decreases in LTPA intensity will have symmetric relationships with the health checkup result. That is, an increase in LTPA intensity from Level 0 to Level k and a decrease in LTPA intensity from Level k to Level 0 are assumed to be accompanied with changes in the health checkup result by β_k and $-\beta_k$, respectively. This assumption aids simplicity and is common to conventional regression models. Secondly, the difference between the estimated coefficients on two LTPA intensity levels indicates the change in the value of the health checkup item with a shift in LTPA intensity between the two levels. This means that the choice of a reference LTPA level does not matter for the estimation results.

However, the statistical problem to be addressed is that the pooled ordinary least squares (OLS) model cannot be used to obtain an unbiased estimator, because η_i is unobserved and thus cannot be used in regressions. Hence, we employed two types of fixed effects model. The first, a first-difference fixed effects model, differentiates both the dependent and independent variables and regresses the first-difference independent variable Δy_{it} (= y_{it} - y_{it-1}) on the first-difference time-variant variables ΔX_{it} (= X_{it} - X_{it-1}). Time-invariant variables, both observed and unobserved, were eliminated.

In this model, we took the first-difference for all binary variables (LTPA intensity, job type, alcohol consumption, and smoking), as well as for continuous variables. For example, if an individual reported changing their LTPA from Level 1 at wave 1 to Level 2 at wave 2, the first-differences for Level 1 and Level 2 at wave 2 are equal to -1 and +1, respectively. In the same way, if the subject reported a change in job type from a clerk to a manager at wave 2, the first-difference variable for a manager at wave 2 is equal to +1, and that of a clerk is equal to -1 (unless either of them is a reference job type).

To examine the robustness of these estimation results, we used a second type of fixed effects model, the mean-centered fixed effects model. This model subtracted the mean over time from the actual value for each variable, thus removing all time-invariant variables from the regression[20]. The same was applied to all binary variables. For example, if an individual reported values of 0, 1, 1, and 0 for a binary variable at waves 1 to 4, respectively, we converted theses values to -0.5, 0.5, 0.5, and -0.5, by subtracting the mean over four waves (0.5) from each actual value. We estimated these two types of fixed effects model separately for male and female subjects.

Results

Table 1 summarizes (A) the basic characteristics of the respondents, which were assessed at baseline in terms of age, household income, hours worked, educational attainment, smoking, alcohol drinking, job type, and firm code and type of industry and (B) prevalence of leisure-time physical activity over the four waves. Over the four waves of reporting, 57.6% of all men and 71.0% of all women surveyed reported performing no LTPA, and less than 5% overall reported performing vigorous-intensity LTPA.

Table 2 presents the transition matrix, which shows how the respondents changed LTPA intensity between two consecutive waves. More than 80% of inactive respondents remained inactive between consecutive waves, and around half of active respondents remained at the same level of intensity. Of the active respondents, 5.0%-13.4% increased the intensity of their LTPA by one level between waves, while 18.2%-39.2% decreased intensity by one level.

Table 3 summarizes key facts about 10 health checkup items, presenting the number of observations, individuals, means, and standard deviations calculated for each of the 10 health checkup items. We made comparisons between the mean values for health checkup items across LTPA levels, and tested health checkup results for statistical associations with LTPA levels using the pooled cross-sectional data.

This table confirms that values for each health checkup item differed substantially between men and women, suggesting that the associations between LTPA and health should be examined separately for each gender. For males, triglyceride, LDL cholesterol, fasting blood glucose, and waist circumference were negatively associated with LTPA levels, while HDL cholesterol and BMI were positively associated with LTPA intensity. For women, fasting blood glucose and waist circumference were negatively associated with LTPA levels, while HDL cholesterol was positively associated.

Table 4 shows the estimated association between intensity levels of LTPA and health checkup results, based on the results of the first-difference fixed effects models for men (top panel) and women (bottom), respectively. The figures reported in the second to fourth columns show the estimated coefficients on binary variables of Levels 1 to 3. These can be interpreted as expected changes in health checkup results as LTPA intensity increases to each level, beginning from Level 0. The figures reported in the fifth to seventh columns present the differences between the estimated coefficients on two LTPA intensity levels, comparing Levels 1 and 2, 1 and 3, and 2 and 3, respectively. These figures can be interpreted as expected changes in health checkup results as LTPA intensity increases in each case.

For men, we observed that, at the 5% significance level, increasing LTPA intensity to a low-intensity level was associated with improvement in LDL cholesterol levels, HbA1c levels, BMI, and waist circumference at the 5% significance level. Improvement in triglyceride, HDL cholesterol, and fasting blood glucose levels was associated with increased LTPA intensity to a moderate or vigorous level. Systolic and diastolic blood pressure and total cholesterol levels were not associated with LTPA intensity at the 5% significance level. However, at the 10% significance level, an increase in LTPA intensity to a low level was concurrent with a reduction in systolic blood pressure, while an increase to a moderate level was associated with improved diastolic blood pressure and total cholesterol levels.

Table 4 also presents differences in health checkup results with increased LTPA intensity. Triglyceride levels, which were reduced when LTPA intensity was increased to a moderate level (third column), were further reduced when intensity increased to a vigorous level (seventh column). We observed similar additional improvement at vigorous-intensity levels of LPTA for HDL cholesterol levels and waist circumference, and, to lesser extent (at the 10% significance level), LDL cholesterol levels. In contrast, reduction in HbA1c levels, which was associated with increased LTPA intensity to a low level (second column), was not associated with further increased intensity to moderate or vigorous levels (fifth and sixth columns). In addition, blood pressure (both systolic and diastolic), total cholesterol levels, fasting blood glucose levels, and BMI did not improve with increased LTPA intensity from the low-intensity level.

In females, both systolic and diastolic blood pressures were reduced when LTPA intensity was increased to a low level, while waist circumference was reduced only when LTPA intensity was increased to a moderate level. Reductions in fasting blood glucose levels were associated with increased LTPA to low-intensity, albeit only at the 10% significance level. For all of these variables, additional increases in LTPA intensity were not associated with further improvement. For the six remaining items, LTPA intensity was generally insignificant.

Table 5 presents the estimation results of the mean-centered fixed effects models. We observed three differences between these estimation results and those of the first-difference fixed effects models. For men, systolic blood pressure was not associated with LTPA, although declines in total cholesterol levels were associated with increased LTPA intensity to “moderate” at the 5% signifi-

Table 1. Basic characteristics of respondents at baseline and prevalence of leisure-time physical activity at different intensity levels over the four waves

		Men	Women	All
(A) Basic characteristics of respondents at baseline				
		M (SD)	*M (SD)*	*M (SD)*
Age (years)		41.0 (10.7)	38.1 (10.3)	40.3 (10.6)
Equivalized household income (annual, million yen)		4.44 (2.03)	3.77 (2.26)	4.28 (2.11)
Hours worked per week		43.4 (9.8)	35.4 (13.2)	41.5 (11.3)
			Proportion (%)	
Educational attainment				
	High school or below	41.4	39.1	40.9
	Junior college	12.1	30.5	16.5
	College	34.3	26.5	32.4
	Graduate school	12.3	4.0	10.3
Smoking		34.1	10.7	28.4
Drinking	Seldom	31.0	53.4	36.4
	Sometimes	36.1	35.5	35.9
	Almost every day	32.9	11.1	27.7
Job type	Managers	20.2	2.2	15.9
	Professionals	14.0	23.9	16.4
	Technicians	13.7	3.5	11.2
	Clerks	9.2	30.7	14.4
	Service and sales workers	4.6	3.0	4.2
	Craft and related trades workers	8.7	2.3	7.2
	Machine operators and assemblers	12.7	4.0	10.6
	Laborers	6.1	13.7	7.9
	Others	10.8	16.7	12.2
Firm code and type of industry				
	1. Information technology	8.5	7.3	8.2
	2. Hospital	1.5	15.6	4.9
	3. Manufacturing	25.8	9.9	22.0
	4. Information	6.4	9.9	7.2
	5. Pharmaceutical	2.0	7.4	3.3
	6. Service	0.2	0.7	0.3
	7. Veterinary	0.0	0.3	0.1
	8. Medical	0.2	0.8	0.3
	9. Service	5.5	8.2	6.2
	10. Manufacturing	29.1	33.7	30.2
	11. Transportation	17.6	2.1	13.8
	12. Real estate	2.7	3.0	2.8
	13.[a] Real estate	0.5	1.1	0.6
Number of individuals at baseline		7,669	2,437	10,106
(B) Prevalence of leisure-time physical activity at different intensity levels				
			Proportion (%)	
Level 0 (inactive)		57.6	71.0	60.7
Level 1 (low)		23.7	17.6	22.3
Level 2 (moderate)		14.5	8.8	13.2
Level 3 (vigorous)		4.1	2.5	3.7
Number of observations over the four waves		23,219	6,987	30,206

Note: [a] A subsidiary of firm 12. Both firms 12 and 13 were real estate.

Table 2. Transition matrix of leisure-time physical activity intensity between two consecutive waves

Intensity level	Intensity level at the subsequent wave [*N* (%)]				
	0	1	2	3	Total
Men					
Level 0	7,825 (83.0)	1,189 (12.6)	329 (3.5)	81 (0.9)	9,424 (100)
1	1,177 (30.5)	2,069 (53.7)	517 (13.4)	91 (2.4)	3,854 (100)
2	267 (11.0)	611 (25.2)	1,371 (56.6)	172 (7.1)	2,421 (100)
3	47 (7.1)	99 (15.0)	182 (27.5)	334 (50.5)	662 (100)
Women					
Level 0	2,992 (86.3)	365 (10.5)	89 (2.6)	21 (0.6)	3,467 (100)
1	323 (39.2)	338 (47.0)	98 (11.9)	16 (1.9)	825 (100)
2	78 (17.8)	117 (26.8)	220 (50.3)	22 (5.0)	437 (100)
3	18 (14.9)	19 (15.7)	22 (18.2)	62 (51.2)	121 (100)
All					
Level 0	10,817 (83.9)	1,554 (12.1)	418 (3.2)	102 (0.8)	12,891 (100)
1	1500 (32.1)	2,457 (52.5)	615 (13.1)	107 (2.3)	4,679 (100)
2	345 (12.1)	728 (25.5)	1591 (55.7)	194 (6.8)	2,858 (100)
3	65 (8.3)	118 (15.1)	204 (26.1)	396 (50.6)	783 (100)

Table 3. Key features of health checkup items

	Number of obser-vations	Number of individuals	*M*	*(SD)*	*M* at leisure-time physical activity level				Trend[a]
					0	1	2	3	
Men									
Systolic blood pressure (mmHg)	23,219	7,669	122.78	(15.18)	122.78	122.60	123.37	122.75	
Diastolic blood pressure (mmHg)	23,219	7,669	76.16	(11.82)	76.07	76.90	75.47	75.50	
Triglyceride (mg/dL)	20,633	7,004	134.38	(114.76)	137.22	137.94	123.83	110.74	(–)***
HDL cholesterol (mg/dL)	21,329	7,199	59.07	(15.02)	58.22	58.92	61.24	64.56	(+)***
LDL cholesterol (mg/dL)	21,170	7,112	119.81	(30.48)	119.96	120.74	118.10	118.25	(–)*
Total cholesterol (mg/dL)	7,149	2,775	198.53	(33.03)	198.33	198.93	197.69	201.81	
Fasting blood glucose (mg/dL)	10,953	3,608	95.15	(18.06)	95.71	94.74	93.62	95.97	(–)**
HbA1c (%)	19,085	6,515	5.20	(0.60)	5.21	5.21	5.18	5.21	
BMI (kg/m^2)	7,500	3,288	23.48	(3.46)	23.32	23.93	23.44	23.44	(+)**
Waist circumference (cm)	17,818	6,418	82.99	(9.10)	83.22	83.23	82.16	81.29	(–)***
Women									
Systolic blood pressure (mmHg)	6,987	2,437	112.49	(14.65)	112.62	112.23	111.88	112.90	
Diastolic blood pressure (mmHg)	6,985	2,436	68.63	(10.95)	68.57	68.89	68.40	69.39	
Triglyceride (mg/dL)	6,481	2,293	79.30	(49.53)	80.02	78.61	72.34	87.23	
HDL cholesterol (mg/dL)	6,493	2,319	71.55	(15.36)	71.33	71.69	72.30	73.99	(+)*
LDL cholesterol (mg/dL)	6,511	2,298	110.54	(28.71)	110.72	110.84	109.34	107.96	
Total cholesterol (mg/dL)	2,525	967	191.81	(31.52)	192.20	190.93	190.62	191.92	
Fasting blood glucose (mg/dL)	3,949	1,402	87.89	(11.19)	88.15	87.60	86.15	88.96	(–)*
HbA1c (%)	5,151	1,854	5.11	(0.42)	5.10	5.15	5.08	5.19	
BMI (kg/m^2)	2,504	1,137	21.48	(3.50)	21.46	21.60	21.66	20.73	
Waist circumference (cm)	4,522	1,693	76.47	(9.42)	76.68	76.46	75.28	75.11	(–)**

Note: [a] Assessed by regressing the four-point scale variable of leisure-time physical activity on the value of each health checkup item. (+) and (–) indicate significant associations, positive and negative, respectively, between the estimated coefficient and the leisure-time physical activity level. ***$p<0.001$, **$p<0.01$, *$p<0.05$.

Table 4. Estimated associations between the intensity levels of leisure-time physical activity and health checkup results: first-difference fixed effects models[a]

Intensity level of leisure-time physical activity[b]	Level 1 (A) (SE)	Level 2 (B) (SE)	Level 3 (C) (SE)	(B)–(A) (SE)	(C)–(A) (SE)	(C)–(B) (SE)
Men						
Systolic blood pressure (mmHg)	–0.41† (0.25)	–0.62† (0.34)	–0.45 (0.55)	–0.21 (0.30)	–0.05 (0.54)	0.17 (0.53)
Diastolic blood pressure (mmHg)	–0.25 (0.18)	–0.46† (0.25)	–0.54 (0.41)	–0.21 (0.23)	–0.29 (0.40)	–0.08 (0.39)
Triglyceride (mg/dL)	0.48 (2.05)	–5.80* (2.86)	–15.98*** (4.54)	–6.28* (2.26)	–16.46*** (4.41)	–10.18* (4.29)
HDL cholesterol (mg/dL)	–0.04 (0.16)	0.51* (0.23)	1.35*** (0.36)	0.55** (0.21)	1.39*** (0.35)	0.84* (0.34)
LDL cholesterol (mg/dL)	–0.90* (0.42)	–1.87** (0.59)	–1.33 (0.93)	–0.97† (0.52)	–0.42 (0.90)	0.54 (0.88)
Total cholesterol (mg/dL)	0.07 (0.86)	–2.24† (1.21)	–1.18 (1.91)	–2.31* (1.02)	–1.25 (1.86)	1.06 (1.81)
Fasting blood glucose (mg/dL)	0.71 (0.39)	–1.33* (0.55)	–2.21** (0.85)	–0.62 (0.43)	–1.50† (0.83)	–0.88 (0.80)
HbA1c (%)	–0.04*** (0.01)	–0.03* (0.02)	–0.07** (0.02)	0.01 (0.01)	–0.03 (0.02)	–0.04 (0.02)
BMI (kg/m^2)	–0.08** (0.03)	–0.14** (0.04)	–0.19* (0.07)	–0.06 (0.04)	–0.11 (0.07)	–0.05 (0.07)
Waist circumference (cm)	–0.16* (0.07)	–0.39*** (0.11)	–0.66*** (0.17)	–0.23* (0.10)	–0.51** (0.16)	–0.27+ (0.16)
Women						
Systolic blood pressure (mmHg)	–1.18** (0.41)	–1.19† (0.61)	–0.86 (1.08)	–0.01 (0.59)	0.32 (1.08)	0.33 (1.10)
Diastolic blood pressure (mmHg)	–0.73* (0.32)	–1.07* (0.49)	–1.16 (0.86)	–0.34 (0.47)	–0.43 (0.86)	–0.09 (0.88)
Triglyceride (mg/dL)	–1.73 (1.76)	–2.34 (2.71)	1.59 (4.58)	–0.61 (2.63)	3.32 (4.58)	3.93 (4.67)
HDL cholesterol (mg/dL)	–0.19 (0.34)	–0.57 (0.52)	0.49 (1.89)	–0.38 (0.51)	0.68 (0.89)	1.06 (0.90)
LDL cholesterol (mg/dL)	–0.68 (0.71)	–0.85 (1.08)	–0.99 (1.85)	–0.17 (1.05)	–0.30 (1.85)	–0.14 (1.88)
Total cholesterol (mg/dL)	–1.45 (1.28)	–2.80 (1.85)	–2.51 (3.38)	–1.35 (1.74)	–1.05 (3.32)	0.29 (3.28)
Fasting blood glucose (mg/dL)	–0.90† (0.47)	–1.23† (0.72)	0.58 (1.29)	–0.33 (0.70)	1.48 (1.28)	1.81 (1.29)
HbA1c (%)	0.01 (0.01)	–0.03 (0.02)	–0.04 (0.04)	–0.04† (0.02)	–0.05 (0.04)	–0.01 (0.04)
BMI (kg/m^2)	0.00 (0.05)	0.08 (0.08)	–0.05 (0.14)	0.08 (0.08)	–0.04 (0.14)	–0.13 (0.14)
Waist circumference (cm)	–0.25 (0.16)	–0.52* (0.26)	–0.24 (0.41)	–0.28 (0.25)	0.01 (0.41)	0.28 (0.43)

Note: [a] Controlled for age, household income, job type, hours worked per week, drinking, smoking, and survey waves.
[b] Level 1: "low," 2: "moderate," 3: "vigorous," and Level 0 used as a reference.
***p<0.001, **p<0.01, *p<0.05, † p<0.1

cance level. For women, declines in waist circumference were associated with low-intensity LTPA, albeit at the 10% significance level. Despite these differences, results from mean-centered fixed effects models were largely consistent with those of the first-difference fixed effects models.

Table 5. Estimated associations between the intensity levels of leisure-time physical activity and health checkup results: mean-centered fixed effects models[a]

Intensity levels of leisure-time physical activity[b]	Level 1 (A) (SE)	Level 2 (B) (SE)	Level 3 (C) (SE)	(B)–(A) (SE)	(C)–(A) (SE)	(C)–(B) (SE)
Men						
Systolic blood pressure (mmHg)	–0.16 (0.25)	–0.44 (0.34)	–0.48 (0.55)	–0.28 (0.32)	–0.32 (0.54)	–0.04 (0.53)
Diastolic blood pressure (mmHg)	–0.18 (0.18)	–0.45† (0.25)	–0.41 (0.41)	–0.27 (0.23)	–0.23 (0.40)	0.04 (0.39)
Triglyceride (mg/dL)	–0.05 (2.16)	–6.81* (3.00)	–17.40*** (4.74)	–6.76* (2.78)	–17.36*** (4.63)	–10.59* (4.53)
HDL cholesterol (mg/dL)	0.10 (0.16)	0.87*** (0.23)	1.77*** (0.36)	0.77*** (0.21)	1.67*** (0.35)	0.90** (0.35)
LDL cholesterol (mg/dL)	–1.26** (0.42)	–2.28*** (0.59)	–2.07* (0.93)	–1.02† (0.54)	–0.81 (0.91)	0.21 (0.89)
Total cholesterol (mg/dL)	0.10 (0.88)	–2.53* (1.25)	–0.69 (1.93)	–2.63* (1.15)	–0.79 (1.89)	1.83 (1.83)
Fasting blood glucose (mg/dL)	–0.48 (0.39)	–1.16* (0.53)	–2.04* (0.84)	–0.68 (0.49)	–1.57† (0.73)	–0.89 (0.80)
HbA1c (%)	–0.04*** (0.01)	–0.03* (0.01)	–0.06* (0.02)	0.00 (0.01)	–0.02 (0.02)	–0.02 (0.02)
BMI (kg/m^2)	–0.06* (0.03)	–0.12** (0.05)	–0.20** (0.07)	–0.06 (0.04)	–0.14† (0.07)	–0.08 (0.07)
Waist circumference (cm)	–0.24** (0.08)	–0.51*** (0.11)	–0.73*** (0.17)	–0.27** (0.10)	–0.49** (0.17)	–0.23 (0.16)
Women						
Systolic blood pressure (mmHg)	–0.85* (0.41)	–1.05† (0.61)	–0.47 (1.09)	–0.20 (0.60)	0.38 (1.10)	0.58 (1.11)
Diastolic blood pressure (mmHg)	–0.76* (0.32)	–1.13* (0.48)	–0.77 (0.86)	–0.37 (0.47)	–0.01 (0.87)	0.36 (0.88)
Triglyceride (mg/dL)	–2.75 (1.74)	–4.95† (2.63)	1.26 (4.51)	–2.20 (2.60)	4.01 (4.54)	6.21 (4.60)
HDL cholesterol (mg/dL)	–0.17 (0.35)	–0.47 (0.52)	0.93 (0.91)	–0.30 (0.52)	1.10 (0.91)	1.40 (0.93)
LDL cholesterol (mg/dL)	–0.56 (0.72)	–1.19 (1.07)	0.24 (1.85)	–0.62 (1.06)	0.81 (1.87)	1.43 (1.89)
Total cholesterol (mg/dL)	–1.59 (1.27)	–2.83 (1.84)	–2.82 (3.22)	–1.24 (1.75)	–1.23 (3.18)	0.01 (3.19)
Fasting blood glucose (mg/dL)	–0.76 (0.49)	–1.26† (0.73)	1.47 (1.30)	–0.49 (0.71)	2.23† (1.30)	2.72* (1.31)
HbA1c (%)	0.01 (0.01)	–0.03 (0.02)	–0.05 (0.04)	–0.04† (0.02)	–0.05 (0.04)	–0.02 (0.04)
BMI (kg/m^2)	0.02 (0.06)	0.06 (0.09)	0.00 (0.14)	0.05 (0.08)	–0.02 (0.14)	–0.06 (0.14)
Waist circumference (cm)	–0.31† (0.17)	–0.56* (0.27)	–0.24 (0.43)	–0.26 (0.26)	0.06 (0.43)	0.32 (0.45)

Note: [a] Controlled for age, household income, job type, hours worked per week, drinking, smoking, and waves.
[b] Level 1: "low," 2: "moderate," 3: "vigorous," and Level 0 used as a reference.
***p<0.001, **p<0.01, *p<0.05, †p<0.1

Based on results from both types of model, Table 6 summarizes the lowest levels of LTPA intensity that were associated with improvement in each health checkup item, as well as additional changes in these variables when LTPA intensity was increased from that level. The table compares the results between first-difference and

Table 6. Lowest intensity level of leisure-time physical activity associated with improvement in health checkup items[a]

	Lowest intensity level associated with improvement in health checkup items		Additional improvement with increased intensity from the lowest intensity level?	
	First difference	Mean centered	First difference	Mean centered
Men				
Systolic blood pressure	*1. Low*	_	No	No
Diastolic blood pressure	*2. Moderate*	*2. Moderate*	No	No
Triglyceride	2. Moderate	2. Moderate	Yes	Yes
HDL cholesterol	2. Moderate	2. Moderate	Yes	Yes
LDL cholesterol	1. Low	1. Low	*Yes*	*Yes*
Total cholesterol	*2. Moderate*	2. Moderate	No	No
Fasting blood glucose	2. Moderate	2. Moderate	No	No
HbA1c	1. Low	1. Low	No	No
BMI	1. Low	1. Low	No	*Yes*
Waist circumference	1. Low	1. Low	Yes	Yes
Women				
Systolic blood pressure	1. Low	1. Low	No	No
Diastolic blood pressure	1. Low	1. Low	No	No
Fasting blood glucose	*2. Moderate*	*2. Moderate*	No	No
Waist circumference	2. Moderate	*1. Low*	No	No
Other items	_	_	_	_

Note: [a] Based on the results shown in Tables 3 and 4. *Italics* indicate significance at the 10%, but not the 5%, confidence level.

mean-centered fixed effects models.

To assess the reliability of these results, we ran the regression models without covariates, which allowed us to utilize a wider set of observations (31,708 observations from 10,467 individuals, compared with 30,206 observations from 10,106 individuals used in Tables 4 and 5). We found that the estimation results (available upon request from the authors) remained generally unchanged.

Discussion

We investigated the associations between changes in LTPA intensity and worker health in Japan using an occupational panel survey. We focused on the relatively short-term association between LTPA and health, utilizing results from annual workplace health checkups.

Our overall findings indicate that performance of LTPA is generally favorably associated with worker health, consistent with observations from previous cohort studies[2-6,10,13,14,17,18]. These preceding studies typically investigated relatively longer-term impacts of LTPA on health, compared with the present study. We observed that commencement of LTPA was associated with improvement in most health checkup items, particularly among male workers.

Our observations also suggest that even low- or moderate-intensity LTPA can yield significant improvements in many health checkup items. This is consistent with results from one systematic review, which reported the greatest improvement in worker health when individuals increased their activity from none to low levels[23]. In the case of male workers, our results indicate that increasing LTPA intensity to a moderate level is associated with improvements in triglyceride, HDL cholesterol, and fasting blood glucose levels. Even low-intensity LTPA appears to be associated with improvements in LDL cholesterol levels, HbA1c levels, BMI, and waist circumference. Blood pressure and total cholesterol vary less with LTPA levels, but low- or moderate-intensity LTPA is modestly associated with their improvement. For women, blood pressure (both systolic and diastolic) appears to decline with performance of low-intensity LTPA, and fasting blood glucose levels and waist circumference improve modestly when LTPA intensity is increased to a moderate level.

Furthermore, we found that increasing LTPA intensity from the lowest levels that were associated with improvements in health checkup items had no relationship with additional improvement in some items. In the case of men, blood pressure, total cholesterol, and fasting blood glucose levels did not change when LTPA intensity was increased from the lowest level. For women, no item changed with increased LTPA intensity.

However, we cannot rule out the possibility that the association between LTPA intensity and health has been underestimated, largely due to two reasons. First, the proportion of respondents reporting moderate- and vigorous-intensity LTPA (including those who adjusted their LTPA to these levels) was limited in the current dataset (Table 2), presumably causing relatively large deviations in health outcome values among those respondents, and reducing statistical power. Second, we focused on the relatively short-term association between LTPA and health, neglecting the long-term effects of increased LTPA intensity. Increasing or even just sustaining levels of LTPA intensity may improve health over a longer time.

We observed that associations with LTPA intensity differed substantially across health checkup items and between genders. Improvements in some health checkup items were associated with increasing LTPA intensity to a moderate level, while others showed improvements even with low-intensity LTPA. Women's health was generally less responsive to changes in LTPA intensity than men's health, while LTPA was more closely associated with improvement in women's blood pressure. However, we should be cautious in interpreting these gender differences, because women comprised less than one fourth of the entire sample.

We recognize that the present study had several limitations. Regarding the study sample, the J-HOPE questionnaire allowed for the case of a combination of different LTPA intensities. The actual association between LTPA intensities and health may be more nuanced than found in the current study. Additionally, we did not control for attrition biases, although attrition rates were relatively low (13.2%-18.3%). Regarding regression analysis, we assumed that increases and decreases in LTPA intensities had symmetric relationships with health, as is the case in most conventional regression models. This assumption may be questionable, and we should examine the associations, which are potentially asymmetric, using a more sophisticated method with a larger sample.

In addition, several issues from the current study remain to be addressed. We did not consider respondent medicine-taking behaviors due to a lack of data availability. For instance, a prescribed dose of medicine based on checkup results may affect results at subsequent checkups, regardless of any change in LTPA. Changes in dietary habits, information that was not available from the current dataset, could also confound the association between LTPA and health checkup results. Furthermore, we did not take into account the impact of occupational and commuting physical activities, which have been found to affect workers' health independently, and may also interact with LTPA[12,24-26]. Most importantly, the fixed effects models could not identify one-way causality between LTPA and health checkup results, although they did control for time-invariant individual attributes. We cannot rule out reverse causation between LTPA and health; for instance, there may be cases of deteriorating health conditions that could limit LTPA.

Despite these limitations, the results of this study suggest that that even light- to moderate-intensity LTPA can improve health checkup results, particularly in men. These findings suggest that encouraging workers who are inactive in leisure time to engage in any physical activity should be a top priority in order to promote their health. This is particularly important in Japan, given the increased prevalence of physical inactivity compared with many other countries[28].

Our results also suggest that the lowest LTPA intensity that is associated with improvement in health for particular outcomes depends on types of health-risk factors as well as gender. In-depth knowledge about the association between LTPA and specific health risks can help occupational health staff to provide workers with practical advice on improving their lifestyle habits, based on the results of health checkups. This advice may allow workers to make the best use of health checkups to promote and manage their own health[29].

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