Television viewing time, walking time, and risk of type 2 diabetes in Japanese men and women: The Japan Collaborative Cohort Study

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ABSTRACT

We examined the effect of television viewing and walking on the risk of type 2 diabetes among an Asian population. A total of 25,240 participants (9786 men and 15,454 women) aged 40–79 years, with no history of diabetes, stroke, coronary heart disease, or cancer at the baseline (1988–1990) and who have completed the 5-year follow-up questionnaire were included. During the 5-year follow-up, 778 new cases of type 2 diabetes were reported (397 men and 381 women). Television viewing time was positively associated with risk of type 2 diabetes (p for trend = 0.01). The multivariable OR (95% CI) for ≥ 5 h/day versus < 2 h/day television viewing was 1.51 (1.03–2.19) in women and 1.06 (0.71–1.59) in men (p for interaction = 0.82). Walking time was inversely associated with type 2 diabetes risk in a fully adjusted model (p for trend = 0.02). The multivariable OR for type 2 diabetes of ≥ 1 h/day walking time was 0.87 (0.71–1.06) compared with 0.5 h/day walking time. The inverse association was found in men (p for trend = 0.02), but not in women (p for trend = 0.38) (p for interaction = 0.36). The multivariable OR for type 2 diabetes of < 5 h/day television viewing and ≥ 1 h/day walking times was 0.72 (0.55–0.94) in fully adjusted model compared with ≥ 5 h/day television viewing and < 1 h/day walking times. Limiting television viewing time and increasing walking time may reduce risk of type 2 diabetes among Japanese.

1. Introduction

In 2014, the number of adults with diabetes in the world has reached 422 million (World Health Organization, 2016). Based on a patient survey conducted in Japan, the estimated number of patients with diabetes has increased from 2.12 million in 1999 to 3.17 million in 2014 (Ministry of Health, Labour and Welfare, 2014).

Several previous prospective cohort studies conducted among American (Hu et al., 2001, 2003; Krishnan et al., 2009; Joseph et al., 2016) and German (Ford et al., 2010) men and women and a meta-analysis (Grøntved and Hu, 2011) reported that prolonged television viewing, a common sedentary behavior, is associated with increased risk of type 2 diabetes. This meta-analysis of 4 prospective cohort studies showed that every 2 h increment in television viewing time per day was associated with 20% increase in type 2 diabetes risk (Grøntved and

Hu, 2011). In Japan, the average daily television viewing time spent in 2010 was approximately 3–4 h (Kobayashi et al., 2011). Although television viewing is a common daily sedentary behavior, few prospective studies have examined the effect of time spent viewing television on the risk of type 2 diabetes among the Asian populations. Japanese and East Asians have lower body mass index than do Caucasians (Yatsuya et al., 2014). Nevertheless, compared with Caucasians, Japanese are predisposed toward type 2 diabetes due to their lower capacity for insulin secretion (Kodama et al., 2013).

Meanwhile, a growing body of studies has shown that physical activity is an effective and modifiable lifestyle factor that can prevent the occurrence of type 2 diabetes. A meta-analysis has shown that participants who walked regularly had 15% reduced type 2 diabetes risk compared with those who spent almost no time walking (Aune et al., 2015). However, some Japanese studies reported the inconsistent

association between walking time and reduced risk of type 2 diabetes (Nakanishi et al., 2004; Sato et al., 2007; Kabeya et al., 2016). A 7-year follow-up study of 2924 male office workers showed that the behaviors of walking or cycling and brisk walking were not significant associated with risk of type 2 diabetes (Nakanishi et al., 2004). The Kansai Healthcare Study of 8576 Japanese male employees reported that time spent walking to work and daily energy expenditure were inversely associated with risk of type 2 diabetes during 4-year follow-up (Sato et al., 2007). The Japan Public Health Center-based Prospective Diabetes study of middle-aged men and women showed that the odds ratio (OR) of type 2 diabetes for < 0.5 h/day walking was 1.23 (95% confidence interval (CI): 1.02–1.48) compared with 2 h/day walking in cross-sectional analysis for 9492 men and 16,996 women, but in the longitudinal analysis of 5-year follow-up for 3691 men and 7410 women, no association was found between walking time and risk of type 2 diabetes (Kabeya et al., 2016).

In this study, we examined the sex-specific associations of television viewing time, walking time and the combination of these behaviors with risk of type 2 diabetes among Japanese men and women using the data of a large prospective cohort study.

2. Methods

2.1. Study population

The baseline survey of the Japan Collaborative Cohort Study for Evaluation of Cancer Risk sponsored by Monbusho (JACC Study) was conducted between 1988 and 1990. A total of 110,585 non-institutionalized residents (46,395 men and 64,190 women) aged 40–79 years from 45 areas throughout Japan were enrolled in the baseline survey (Tamakoshi et al., 2013). Informed consent was obtained individually and directly from the members of the cohort in most regions, whereas it was obtained at the community level after the purpose of the study and confidentiality of the data had been explained to community leaders and mayors in several areas. Participants were recruited mostly when they took a health checkup and others were done by household survey. They completed a self-administered questionnaire at baseline: response rate was 83% (Tamakoshi et al., 2005). We conducted the 5-year follow-up survey in 31 of the 45 areas involved in the baseline survey. A total of 46,540 persons completed the 5-year follow-up survey, of whom 32,403 participants had available baseline information on television viewing and walking times. Subsequently, we excluded 3448 persons who had diabetes, cancer, stroke, and coronary heart disease at the baseline, and 3715 persons from the 5-year follow-up survey whose data on diabetes incidence were unavailable. Finally, 25,240 participants were included in this study. Mean body mass index did not differ between the respondents and nonrespondents: 22.6 kg/m^2 and 22.5 kg/m^2 in men, and 22.8 kg/m^2 and 22.9 kg/m^2 in women. The study design was approved by the Ethics Committees of Hokkaido University and Osaka University.

2.2. Baseline survey

The baseline data were collected using self-administered questionnaire that included queries on demographic characteristics, medical history, and lifestyle habits. We obtained information on the average daily time spent viewing television during the past year from the baseline survey: 'On average how many hours do you watch TV?' The participants reported their time spent viewing TV a day: 'approximately ☐ h/day.' Subsequently, television viewing times were classified into 5 categories: < 2, 2, 3, 4, and ≥ 5 h/day. The categories of television viewing time were determined based on our previous studies (Ukawa et al., 2018; Ikehara et al., 2015). Participants were asked about the average daily time spent walking; 'How long on average do you spend walking indoors or outside on daily basis?', which included 4 options: < 0.5, 0.5, 0.6–0.9 h, and ≥ 1 h/day. We regarded 'walking' as

daily light-to-moderate intensity physical activity. Unfortunately, the questionnaire on television viewing time and walking time has not been validated. However, the reliability of walking time was examined about one year apart in 416 men and 636 women: weighted kappa coefficients = 0.32 in men and 0.31 in women (Iwai et al., 2001). We used the following variables as potential risk factors: smoking, alcohol intake, hours of exercise, perceived mental stress, educational level, unemployed, sleep duration, histories of hypertension and body mass index. As for hours of exercise, we used the validated question; 'What is the average amount of time you spend engaging in sports on a weekly basis?' The answer was obtained from 4 options: < 1 h, 1–2 h, 3–4 h and ≥ 5 h. (Iwai et al., 2001).

2.3. Ascertainment of diabetes

The type 2 diabetes incidence was defined as self-reported physician-diagnosed diabetes at the 5-year follow-up survey. The validity of self-reporting physician-diagnosed diabetes was evaluated through comparison of self-reported diabetes with the participants' glucose concentrations or treatments among 1230 men and 1837 women. Diabetes case was defined as ≥ 7.8 mmol/L (≥ 140 mg/dL) fasting serum glucose concentration or ≥ 11.1 mmol/L (≥ 200 mg/dL) randomly measured concentration, or treatment with oral hypoglycemic agents or insulin (Iso et al., 2006). The sensitivity and specificity of self-reporting were 70% and 95%, respectively, for men and 75% and 98%, respectively, for women.

2.4. Statistical analysis

We calculated the age- and sex-adjusted mean values and prevalence of the type 2 diabetes risk factors based on the categories of time spent viewing television and walking. A linear trend was tested using the median value of each television viewing time and walking time category. The OR and 95% CI for type 2 diabetes related to the television viewing time and walking time categories were estimated using logistic regression after adjusting for age, sex, and other potential confounding factors: history of hypertension, smoking (never, ex-smoker, or current smoker of 1–19 or ≥ 20 cigarettes/day), alcohol intake (never, ex-drinker, or current drinker of 0.1–22.9 or ≥ 23.0 g ethanol/day), hours of exercise (< 1, 1–2, 3–4 or ≥ 5 h/week), perceived mental stress (low, moderate, high), educational level (< 13, 13–15, 16–18 or ≥ 19 years), unemployed (yes or no) and sleep duration (< 5.5, 5.5–6.4, 6.5–7.4, 7.5–8.4 or ≥ 8.5 h/day). Further adjustments were made for television viewing time or walking time in model 2. The body mass index (sex-specific quintiles) was added to model 3. We used the second lowest category of walking time as the reference to avoid a potential effect of preclinical ill health. To test for trend, we assigned the value to each category of television viewing and walking times as follows: 1.0 for < 2 h, 2.0 for 2.0 h, 3.0 for 3 h, 4.0 for 4 h and 5.0 for ≥ 5 h/day for television viewing time; 0.25 for < 0.5 h, 0.5 for 0.5 h, 0.75 for 0.6–0.9 h and 1.0 for ≥ 1 h/day for walking time. Statistical interactions were examined by using cross-product terms of television viewing time or walking time and sex. Additionally, we examined the association between the combined television viewing time (< 5 or ≥ 5 h/day) and walking time (< 1 or ≥ 1 h/day) and risk of type 2 diabetes. SAS 9.4 software (SAS Institute Inc., Cary, NC, USA) was used for all statistical analyses.

3. Results

Table 1 shows the age-adjusted mean values and risk factor prevalence at the baseline based on the television viewing and walking time categories. Men and women who had longer television viewing time were more likely to be older, smoker, hypertensive, unemployed, and have higher body mass index, and were less likely to be educated and have perceived mental stress, than their counterparts. Women who

Table 1

Age-adjusted baseline characteristics according to television viewing time or walking time.

	Television viewing (hours/day)					p for trend	Walking (hours/day)				p for trend
	< 2	2	3	4	≥5		< 0.5	0.5	0.6–0.9	≥1.0	
Men											
Persons	1801	3174	2842	1084	885		1014	1662	1870	5240	
Age, years	55.6	55.8	56.9	58.3	62.0	< 0.001	55.0	56.7	57.3	57.2	< 0.001
Mean body mass index, kg/m^2	22.4	22.5	22.6	22.9	22.7	< 0.001	23.0	22.7	22.6	22.4	< 0.001
History of hypertension, %	16.7	16.9	17.6	19.3	20.7	0.006	18.4	19.9	20.4	15.8	< 0.001
Current smokers, %	46.7	49.2	53.1	56.1	56.1	< 0.001	50.6	49.3	49.3	52.7	0.02
Ethanol intake, g/day	34.6	34.1	32.4	33.2	33.3	0.02	33.8	31.8	32.5	34.5	0.005
College or higher education, %	21.6	19.9	16.6	16.3	16.5	< 0.001	18.8	24.6	23.4	14.8	< 0.001
Exercise of 5 h or more/week, %	8.8	8.9	8.1	7.2	8.0	0.11	2.0	3.9	6.8	11.7	< 0.001
High stress, %	26.2	21.8	20.1	17.8	19.6	< 0.001	27.4	27.5	21.2	18.7	< 0.001
Sleep duration, hours	7.4	7.5	7.4	7.4	7.4	0.28	7.4	7.4	7.4	7.5	< 0.001
Unemployed, %	12.1	12.8	16.2	24.2	40.2	< 0.001	18.5	20.4	21.4	14.8	< 0.001
Women											
Persons	2860	4492	4133	1904	2065		1431	2493	3143	8387	
Age, years	54.3	55.6	57.0	57.9	60.9	< 0.001	55.0	56.8	56.9	56.9	< 0.001
Mean body mass index, kg/m^2	22.3	22.7	22.9	23.0	23.2	< 0.001	23.2	22.8	22.7	22.7	< 0.001
History of hypertension, %	17.9	19.5	20.2	21.4	22.1	< 0.001	21.0	22.0	20.3	19.0	0.002
Current smokers, %	2.6	3.5	3.8	5.4	7.8	< 0.001	6.2	3.8	4.4	3.9	0.006
Ethanol intake, g/day	9.5	9.3	9.1	9.8	10.6	0.17	11.6	9.5	9.3	9.4	0.08
College or higher education, %	13.0	9.3	9.6	11.3	9.4	0.01	9.0	12.1	11.0	9.8	0.17
Exercise of 5 h or more/week, %	5.6	4.6	4.4	4.6	4.0	0.03	1.6	1.4	2.8	6.9	< 0.001
High stress, %	23.1	20.2	19.5	17.5	18.2	< 0.001	22.4	20.6	19.6	19.6	0.04
Sleep duration, hours	7.0	7.1	7.1	7.0	7.1	0.22	7.1	7.0	7.0	7.1	0.03
Unemployed, %	43.8	46.1	52.2	58.9	66.2	< 0.001	46.8	55.7	57.0	49.1	0.003

had longer television viewing time were less likely to engage in sport. Men and women who had longer walking time have lower body mass index and lower perceived mental stress and were less likely to be hypertensive and were more likely to be older and engaged in sport compared with 0.5 h/day walking. Men who had longer walking time were less likely to be unemployed and educated, and more likely to be smoker and drinker. Women who had longer walking time were more likely to be unemployed and less likely to be smoker.

During the 5-year follow-up survey, we observed 778 new cases of type 2 diabetes (397 in men and 381 in women). Table 2 presents the

age- and sex-adjusted and multivariable OR (95% CI) for type 2 diabetes according to the television viewing time. Television viewing time was positively associated with risk of type 2 diabetes. The multivariable OR for type 2 diabetes of ≥5 h/day television viewing time was 1.48 (95% CI: 1.14–1.93) compared with < 2 h/day television viewing time (p for trend ≤ 0.001). The association was statistically significant after additional adjustment for walking time (the multivariable OR = 1.44, 95% CI: 1.10–1.88). The multivariable OR of ≥5 h/day television viewing time was attenuated after additional adjustment for body mass index (the multivariable OR = 1.30, 95% CI: 1.00–1.70), but the linear

Table 2

Odds ratio (OR) and 95% confidence interval (CI) of risk of type 2 diabetes according to television viewing time.

	Television viewing time (hours/day)					p for trend
	< 2	2	3	4	≥5	
All						
Number of participants	4661	7666	6975	2988	2950	
Number of cases	117	195	235	100	131	
Age, sex-adjusted OR	1.00	0.98 (0.78–1.24)	1.27 (1.01–1.59)	1.25 (0.96–1.65)	1.60 (1.23–2.07)	< 0.001
Model 1	1.00	0.97 (0.77–1.23)	1.24 (0.99–1.56)	1.20 (0.91–1.58)	1.48 (1.14–1.93)	< 0.001
Model 2	1.00	0.97 (0.77–1.23)	1.23 (0.98–1.55)	1.19 (0.90–1.56)	1.44 (1.10–1.88)	0.001
Model 3	1.00	0.93 (0.74–1.18)	1.16 (0.92–1.46)	1.09 (0.83–1.44)	1.30 (1.00–1.70)	0.01
Men						
Number of participants	1801	3174	2842	1084	885	
Number of cases	67	101	124	55	50	
Age-adjusted OR	1.00	0.85 (0.62–1.16)	1.14 (0.84–1.55)	1.29 (0.90–1.87)	1.33 (0.91–1.95)	0.01
Model 1	1.00	0.87 (0.63–1.19)	1.14 (0.84–1.54)	1.22 (0.84–1.77)	1.19 (0.80–1.76)	0.08
Model 2	1.00	0.87 (0.63–1.19)	1.13 (0.83–1.54)	1.21 (0.83–1.75)	1.14 (0.77–1.70)	0.12
Model 3	1.00	0.84 (0.61–1.16)	1.09 (0.80–1.48)	1.10 (0.76–1.61)	1.06 (0.71–1.59)	0.27
Women						
Number of participants	2860	4492	4133	1904	2065	
Number of cases	50	94	111	45	81	
Age-adjusted OR	1.00	1.16 (0.82–1.64)	1.44 (1.02–2.01)	1.23 (0.81–1.84)	1.89 (1.31–2.71)	< 0.001
Model 1	1.00	1.13 (0.80–1.60)	1.37 (0.98–1.93)	1.18 (0.78–1.79)	1.74 (1.20–2.53)	0.003
Model 2	1.00	1.12 (0.79–1.59)	1.37 (0.97–1.92)	1.16 (0.77–1.76)	1.70 (1.17–2.47)	0.005
Model 3	1.00	1.07 (0.75–1.52)	1.27 (0.90–1.78)	1.06 (0.70–1.61)	1.51 (1.03–2.19)	0.03

Model1: Adjusted for age, sex (excluded for sex-specific analysis), alcohol consumption, history of hypertension, smoking status, hours of exercise, stress, educational level, unemployed, and sleep duration.
Model 2: Adjusted for Model 1 + walking time.
Model 3: Adjusted for Model 2 + body mass index.

Table 3
Odds ratio (OR) and 95% confidence interval (CI) of risk of type 2 diabetes according to walking time.

	Walking time (hours/day)				p for trend
	< 0.5	0.5	0.6–0.9	≥1.0	
All					
Number of participants	2445	4155	5013	13,627	
Number of cases	94	146	162	376	
Age, sex-adjusted OR	1.16 (0.89–1.51)	1.0	0.92 (0.73–1.16)	0.78 (0.64–0.95)	< 0.001
Model 1	1.18 (0.90–1.55)	1.0	0.94 (0.74–1.18)	0.82 (0.67–0.99)	0.001
Model 2	1.18 (0.90–1.54)	1.0	0.94 (0.75–1.18)	0.83 (0.68–1.02)	0.003
Model 3	1.13 (0.86–1.49)	1.0	0.97 (0.77–1.22)	0.87 (0.71–1.06)	0.02
Men					
Number of participants	1014	1662	1870	5240	
Number of cases	57	77	76	187	
Age-adjusted OR	1.30 (0.91–1.84)	1.0	0.86 (0.62–1.19)	0.75 (0.57–0.99)	< 0.001
Model 1	1.32 (0.92–1.90)	1.0	0.87 (0.62–1.20)	0.79 (0.60–1.04)	0.002
Model 2	1.31 (0.91–1.89)	1.0	0.87 (0.62–1.20)	0.79 (0.60–1.05)	0.002
Model 3	1.29 (0.89–1.86)	1.0	0.90 (0.65–1.26)	0.85 (0.64–1.13)	0.02
Women					
Number of participants	1431	2493	3143	8387	
Number of cases	37	69	86	189	
Age-adjusted OR	1.00 (0.67–1.50)	1.0	0.99 (0.71–1.36)	0.81 (0.61–1.07)	0.08
Model 1	0.99 (0.65–1.50)	1.0	1.02 (0.74–1.41)	0.84 (0.63–1.12)	0.17
Model 2	1.00 (0.66–1.52)	1.0	1.03 (0.75–1.43)	0.87 (0.65–1.16)	0.26
Model 3	0.94 (0.62–1.44)	1.0	1.05 (0.76–1.46)	0.88 (0.66–1.17)	0.38

Model1: Adjusted for age, sex (excluded for sex-specific analysis), alcohol consumption, history of hypertension, smoking, hours of exercise, stress, educational level, unemployed and sleep duration.
Model 2: Adjusted for Model 1 + television viewing time.
Model 3: Adjusted for Model 2 + body mass index.

trend remained statistically significant (p for trend = 0.01). The positive association was more evident in women but non-significant sex interaction in relation to risk of type 2 diabetes (p for interaction = 0.82). The multivariable OR of ≥5 h/day television viewing time were 1.06 (0.71–1.59) in men and 1.51 (1.03–2.19) in women.

Table 3 shows the age- and sex-adjusted and multivariable OR (95% CI) of type 2 diabetes according to walking time. Walking time was inversely associated with type 2 diabetes risk. The multivariable OR for type 2 diabetes of ≥1 h/day walking time was 0.82 (95% CI: 0.67–0.99) compared with 0.5 h/day walking time (p for trend = 0.001). The association was attenuated after further adjustment for television viewing time (the multivariable OR = 0.83, 95% CI: 0.68–1.02) (p for trend = 0.003). The multivariable OR of ≥1 h/day walking time became weaker in the fully-adjusted model including adjustment for body mass index (the multivariable OR = 0.87, 95% CI: 0.71–1.06), but the linear trend remained statistically significant (p for trend = 0.02). The inverse associations were evident in men but not in women with no significant sex interaction (p for interaction = 0.36 in the fully-adjusted model).

We examined the combined effect of the time spent viewing television and walking on risk of type 2 diabetes (Table 4), the multivariable OR of type 2 diabetes for < 5 h/day television viewing time and ≥1 h/day walking time was 0.67 (95% CI: 0.51–0.87) compared with ≥5 h/day television viewing time and < 1 h/day walking time. The reduced risk remained statistically significant after further adjustment for body mass index (the multivariable OR = 0.72, 95% CI: 0.55–0.94).

4. Discussion

In this prospective population-based cohort study conducted among Japanese men and women, we found that extended television viewing time was associated with elevated risk of type 2 diabetes, whereas increased walking time tended to be associated with reduced risk of type 2 diabetes. The adverse effect of television viewing on risk of type 2 diabetes was stronger in women, while the beneficial effect of walking was found in men but not in women. Our results also showed that the

combination of < 5 h/day television viewing and ≥1 h/day walking may be effective for prevention of type 2 diabetes.

This study is the first to show the prospective association between television viewing time and risk of type 2 diabetes among the Asian population. The findings related to television viewing time and type 2 diabetes are consistent with those of the previous prospective cohort studies performed among different populations (Hu et al., 2001, 2003; Krishnan et al., 2009; Joseph et al., 2016; Ford et al., 2010). Most of the previous studies revealed that prolonged television viewing time was associated with increased risk of type 2 diabetes, independent of physical activity. A meta-analysis of 4 prospective studies reported that every 2 h increase in television viewing per day was associated with 20% increase in type 2 diabetes risk (Grøntved and Hu, 2011). The mechanisms by which prolonged television viewing time increases risk of type 2 diabetes may include abnormal glucose tolerance (Hamilton et al., 2014; Dunstan et al., 2004, 2007), impaired insulin sensitivity (Hamilton et al., 2014; Dunstan et al., 2007), and adverse lipid metabolism (Hamilton et al., 2014; Fung et al., 2000). Sedentary behaviors have been postulated to induce the reduction of glucose uptake in skeletal muscles though impaired GLUT4 translocation to the skeletal muscle cell membrane, as well as decreased skeletal muscle lipoprotein lipase activity leading to high plasma triglyceride and low high-density lipoprotein cholesterol levels (Hamilton et al., 2014). Increased television viewing time also leads to low energy expenditure and high intake of unhealthy and high-calorie diet (Huffman et al., 2012) resulting in weight gain and obesity, which subsequently cause type 2 diabetes (Hu et al., 2003). In the present study, risk of type 2 diabetes associated with television viewing time was attenuated following adjustment for body mass index, which suggests that the association may be partially mediated by weight gain and obesity (Hu et al., 2001, 2003).

Additionally, walking time was inversely associated with risk of type 2 diabetes in the present study. The inverse association was primarily observed in men but not in women. The insignificant association in women was possibly due to their lower speed and intensity of walking. Several prospective cohort studies conducted among American men (Hu et al., 2001) and women (Hu et al., 2003; Krishnan et al., 2009; Hu et al., 1999; Hsia et al., 2005; Weinstein et al., 2004) showed

Table 4

Odds ratio and 95% confidence interval of risk of type 2 diabetes according to the combined times of television viewing and walking.

	≥5 h TV viewing/ < 1 h walking	≥5 h TV viewing/≥1 h walking	< 5 h TV viewing/ < 1 h walking	< 5 h TV viewing/≥1 h walking
All				
Number of participants	1677	1273	9936	12,354
Number of cases	77	54	325	322
Model 1	1.0	0.94 (0.66–1.34)	0.78 (0.61–1.01)	0.61 (0.47–0.79)
Model 2	1.0	0.98 (0.69–1.41)	0.84 (0.64–1.09)	0.67 (0.51–0.87)
Model 3	1.0	0.98 (0.68–1.40)	0.86 (0.66–1.12)	0.72 (0.55–0.94)
Men				
Number of participants	520	365	4026	4875
Number of cases	28	22	182	165
Model 1	1.0	1.14 (0.64–2.02)	0.98 (0.65–1.48)	0.71 (0.47–1.07)
Model 2	1.0	1.18 (0.66–2.12)	1.10 (0.72–1.67)	0.82 (0.53–1.25)
Model 3	1.0	1.19 (0.66–2.15)	1.11 (0.72–1.70)	0.88 (0.57–1.36)
Women				
Number of participants	1157	908	5910	7479
Number of cases	49	32	143	157
Model 1	1.0	0.83 (0.53–1.30)	0.66 (0.47–0.93)	0.56 (0.40–0.78)
Model 2	1.0	0.85 (0.54–1.34)	0.70 (0.50–0.98)	0.60 (0.43–0.84)
Model 3	1.0	0.84 (0.53–1.33)	0.73 (0.52–1.03)	0.64 (0.45–0.90)

Model1: Adjusted for age and sex (excluded for sex-specific analysis).
Model2: Adjusted for age, sex (excluded for sex-specific analysis), alcohol consumption, history of hypertension, smoking, hours of exercise, stress, educational level, unemployed and sleep duration.
Model3: Adjusted further for body mass index.

the beneficial effect of walking on the reduction of type 2 diabetes risk. A recent meta-analysis reported that the summary hazard ratio of diabetes risk for the highest walking level was 0.85 (95% CI: 0.79–0.91) in total subjects, 0.78 (0.63–0.95) in men and 0.86 (0.80–0.93) in women, compared with the lowest walking level (Aune et al., 2015). Physical activities, including walking, reduce adiposity (Hu et al., 2003) and visceral fat accumulation (Despres, 1997), improve glucose tolerance (Dunstan et al., 2007), and lipid profiles (Warburton et al., 2006).

In the present study, increased risk of type 2 diabetes associated with prolonged television viewing time was evident in women but not in men. The previous studies also reported that the effects of increased television viewing time on abnormal glucose metabolism (Dunstan et al., 2004, 2007) and metabolic syndrome (Dunstan et al., 2005) were stronger in women than in men. An experimental study on fuel homeostasis during 7 days of head-down bed rest showed that the suppression of endogenous glucose production after head-down bed rest was evident in men but not in women, suggesting that insulin resistance occurred at the muscle level in men and at both the muscle and liver levels in women (Blanc et al., 2000). Such a sex difference in glucose metabolism in response to sedentary lifestyle may explain in part the finding from the present and previous studies.

The strength of our analysis lies in its prospective population-based study design. Our study is the first to show the sex-specific association of time spent viewing television and walking with risk of type 2 diabetes, as well as the combination of these behaviors, among the Asian population.

Our study has several limitations to consider when interpreting the results. First, we used self-reported physician-diagnosed diabetes, which may lead to misclassification. However, an earlier study on the same cohort reported the moderate sensitivity and high specificity for self-reported diabetes for the evaluation of diabetes based on plasma glucose levels and treatment with hypoglycemic medications (Iso et al., 2006). Two-point assessments of type 2 diabetes, the baseline and 5-year later in the present study is the weaker design than yearly assessments because the occurrence of diabetes cannot be estimated fully during follow-up. Also, the selection follow-up bias may occur, but mean body mass index at baseline did not differ between the respondents and nonrespondents to the 5-year follow-up questionnaire. Second, the determination of television viewing time was estimated by self-reported, which is prone to misclassification as well. However, a recent Japanese study reported acceptable reliability of television

viewing time: the interclass correlation coefficient was 0.76 for workdays, 0.79 for non-workdays and 0.82 for whole week (Ishii et al., 2018). The validity coefficients of self-reported television viewing time and the combined accelerometer and behavioral log were 0.69 for employed men and 0.83 for employed women; 0.78 for retired men and 0.80 for retired women (Matton et al., 2007).

5. Conclusion

This population-based prospective study of Japanese indicated that prolonged television viewing time was associated with elevated risk of type 2 diabetes, whereas increased walking time was associated with reduced risk of type 2 diabetes risk. Our findings suggest that limited time spent for television viewing and increased time for walking may be effective in reducing risk of type 2 diabetes.

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