



## Impact of Walking on Life Expectancy and Lifetime Medical Expenditure: The Ohsaki Cohort Study

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## **Research**

### **Impact of Walking on Life Expectancy and Lifetime Medical Expenditure: The Ohsaki Cohort Study**

Running Title: Walking and Life Expectancy and Lifetime Medical Cost

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## Abstract

### Objective

People who spend a longer time walking have lower demands for medical care.

However, in view of their longer life expectancy, it is unclear whether their lifetime medical expenditure increases or decreases. The present study examined the association between time spent walking, life expectancy, and lifetime medical expenditure.

### Method

We followed up 27,738 participants aged 40-79 years and prospectively collected data on their medical expenditure and survival covering a 13-year period. Participants were classified into those walking  $<1$  and  $\geq 1$  hour per day. We constructed life tables, and estimated the life expectancy and lifetime medical expenditure from 40 years of age using estimate of multiadjusted mortality and medical expenditure by Poisson regression model and linear regression model, respectively.

### Results

In spite of their longer life expectancy, participants who walked  $\geq 1$  hour per day required lower lifetime medical expenditure than participants who walked  $<1$  hour per day. In men, multiadjusted life expectancy for those who walked  $\geq 1$  hour per day was 44.81 years, which was significantly longer by 1.38 years than that for those who walked  $<1$  hour per day ( $p=0.0073$ ). Multiadjusted lifetime medical expenditure for

those who walked  $\geq 1$  hour per day was £99,423.6, being significantly lower by 7.6% ( $p=0.0048$ ). In women, multiadjusted life expectancy for those who walked  $\geq 1$  hour per day was 57.78 years, which was 1.16 years longer ( $p=0.2351$ ), and multiadjusted lifetime medical expenditure was £128,161.2, being 2.7% lower ( $p=0.2559$ ).

**Discussion**

Increased longevity resulting from a healthier lifestyle does not necessarily translate into an increased amount of medical expenditure throughout life. Encouraging people to walk may extend life expectancy and decrease lifetime medical expenditure.

(268 words)

**Key Words:**

walking; lifetime medical expenditure; life expectancy; physical activity;

## INTRODUCTION

Previous studies have agreed that a higher level of physical activity extends life expectancy.<sup>1-4</sup> Walking is part of a physically active lifestyle. Previous studies have indicated that a longer time spent walking,<sup>5-13</sup> walking pace,<sup>8, 14-16</sup> and a longer distance walked<sup>17, 18</sup> are significantly associated with a decreased risk of mortality.

We previously reported that medical expenditure per month was significantly reduced among those who spent a longer time walking, based on the same cohort dataset as that used here.<sup>19</sup> Similar findings have been reported worldwide.<sup>20, 21</sup> However, in view of the increased life expectancy of those who walk for a longer time, it is unclear whether lifetime medical expenditure increases or decreases as a result. In other words, the question to be answered here is whether a lifelong healthy lifestyle eventually increases lifetime medical expenditure because of extended life expectancy.

So far, only one study has examined the association between physical activity and lifetime costs.<sup>4</sup> This revealed that people with a high physical activity level tended to live longer than people with a lower physical activity level, and that the former had lower lifetime medical costs than the latter. However, that study was only a simulation analysis based on assumed variations in the health and economic effects of active and sedentary lifestyles.

The objective of the present study was to examine the association between walking, life expectancy, and lifetime medical expenditure using actual individual data derived

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from a population-based 13-year prospective observation period. The population comprised 27,738 Japanese adults aged 40-79 years living in the community who were free of any functional limitations or chronic conditions interfering with physical activity, with an accrued total of 285,342 person-years. This cohort study has been monitoring survival and medical care utilization, and its costs, for all participants.<sup>19, 22,</sup>  
<sup>23</sup> Using this dataset, we constructed a life table to estimate life expectancy and lifetime medical expenditure according to the time spent walking.<sup>23-25</sup>

## MATERIALS AND METHODS

### Study cohort

The present data were derived from the Ohsaki National Health Insurance (NHI) Cohort Study.<sup>19, 22, 23, 26</sup> We conducted a self-administered questionnaire survey of various lifestyle habits between October and December 1994 for all NHI beneficiaries aged 40 to 79 years who lived in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan. Out of 54,996 eligible individuals, 52,029 (95%) responded.

We excluded 776 participants who had withdrawn from the NHI before January 1, 1995 because their cost data were not available. Thus, the remaining 51,253 participants formed the study cohort. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

For the present analysis, we excluded participants who had functional limitation or chronic conditions interfering with physical activity. Physical function status was assessed using the 6-item measure of the Medical Outcomes Study (MOS) Short-form General Health Survey.<sup>27</sup> Participants were excluded if they stated on the MOS questionnaire that they were unable to perform moderate or vigorous activities

(n=15,916). We excluded participants who reported severe bodily pain (n=949), or history of stroke (n=474), myocardial infarction (n=585) or arthritis (n=2,176). We also excluded those who died within the first year (n=174) or did not provide complete responses in the walking status questionnaire (n=3,241). Thus, a total of 27,738 participants (15,521 men and 12,217 women) remained. These participants were apparently healthy enough to walk for as long as they wished.

**Time spent walking**

The self-administered questionnaire included items on time spent walking. We divided the participants into two groups according to the time spent walking daily: <1 hour and ≥1 hour. We had previously evaluated and reported the validity of self-reported time spent walking.<sup>5, 19, 28</sup> This validation study had indicated that self-reported walking time was reasonably reproducible and sufficiently valid for studying the health effects of walking.

**Health insurance system in Japan**

Details of the Japanese NHI system have been described previously.<sup>22, 23, 29, 30</sup> Briefly, everyone living in Japan is required to enroll in a health insurance system. The NHI covers 35% of the Japanese population, mainly farmers, self employed, or retired people. The NHI covers almost all medical treatment, including diagnostic tests, medication,

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6 surgery, supplies and materials, physicians and other personnel costs, inpatient care, and  
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9 most dental treatment. It covers treatment by physicians and nurses but not that by  
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12 other professionals such as home health aides. Payment to medical providers is made  
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15 on a fee-for-service basis, where the price of each service is determined by a uniform  
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18 national fee schedule.  
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21 When a participant withdraws from the NHI system because of death, emigration, or  
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23 employment, the withdrawal date and its reason are coded in the NHI withdrawal  
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25 history files. We recorded any mortality or migration by reviewing the NHI  
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27 withdrawal history files and collected data on the death of participants by reviewing the  
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29 death certificates filed at Ohsaki Public Health Center. We thus followed up the  
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31 participants and prospectively collected data on medical care utilization and its costs for  
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34 all individuals in the cohort from January 1 1995 through December 31 2007.  
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### 43 **Statistical analysis**

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45 Using the Ohsaki NHI cohort database, we estimated mortality and medical expenditure  
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47 for individual age-groups, and for the categories of time spent walking, for both men  
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49 and women. We divided age in to the following groups: 40-44, 45-49, 50-54, 55-59,  
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52 60-64, 65-69, 70-74, 75-79, 80-84, and  $\geq 85$  years. The multiadjusted mortality rates  
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55 for each age category were estimated from a Poisson regression model based on  
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58 person-years and the number of deaths from 1996 until 2007. The dependent variable  
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was mortality and independent variables were age-groups, categories of time spent walking, and the following covariates: smoking status (current and past smoker, or never smoker), alcohol consumption (current drinker consuming 1-499 g/week, current drinker consuming  $\geq 450$  g/week, or never and past drinker), body mass index (BMI:  $< 21$  kg/m<sup>2</sup>, 21-24.9 kg/m<sup>2</sup>, or  $\geq 25$  kg/m<sup>2</sup>), self-rated health (good or not good), sports and physical activity ( $\geq 3$  hours/week or  $< 3$  hours/week), history of hypertension (presence or absence), history of diabetes mellitus (presence or absence), history of cancer (presence or absence), history of liver disease (presence or absence), and history of kidney disease (presence or absence).<sup>19</sup> We estimated the mortality of participants aged  $\geq 85$  years by multiplying the estimated mortality for the 85-89 year age-group by the ratio of mortality for the same age-group relative to the mortality for  $\geq 85$  years from complete life tables for the year 2000, as there were few person-years for participants aged over 90 years in our dataset.<sup>31</sup>

Because medical expenditure increases before death, we separately calculated medical expenditure for participants who survived through the index year and for those who died. The multiadjusted medical expenditure per year for survivors and decedents, respectively, was estimated for each of the age-groups and the categories of time spent walking using a linear regression model adjusted for the above covariates.

The estimates of multiadjusted mortality and medical expenditure for each age-group were used for estimating life expectancy and lifetime medical expenditure from 40 years

of age. Life expectancy was calculated using Chiang's analytical method on the basis of the latest published complete life tables of Japan for the year 2000.<sup>23, 24, 31</sup> Lifetime medical expenditure was estimated from the sum obtained by multiplying the static population in life table by the medical expenditure for survivors and the number of deaths in the life table by the increased medical expenditure due to death, which was calculated by subtracting the medical expenditure in year of survivors from that in the period of 1 year before death. That is, life expectancy ( $e_x$ ) and lifetime medical expenditure ( $M_x$ ) for each age-groups (x) were estimated using the numbers of survivors ( $l_x$ ), deaths ( $d_x$ ), static population ( $L_x$ ), multiadjusted medical expenditure for survivors ( $a_y$ ), and multiadjusted medical expenditure for the deceased ( $b_y$ ) as follows;

$\sum_{y \geq x}$  is sum of  $y \geq x$

$$e_x = \frac{\sum L_y}{l_x}$$

$$M_x = \frac{\sum (L_y \cdot a_y + d_y \cdot b_y)}{l_x}$$

The 95% confidence intervals (CIs) were estimated using a Monte Carlo simulation based on a Poisson regression model and linear regression model. We repeated 100,000 times and all analysis were used the SAS version 9.1 statistical software package (SAS Institute Inc., 2004).

We used a purchasing power parity rate of UK£ 1.00=JPN¥ 140.

RESULTS

After 13 years of follow-up, we observed 2,936 deaths (2,193 men and 743 women) among the 27,738 participants (15,521 men and 12,217 women). Mean medical expenditure per year for survivors who walked  $\geq 1$  hour per day was £1,714.2 in men and £1,621.4 in women, being significantly lower than for those who walked  $< 1$  hour per day (men; £2,064.3,  $p < 0.0001$ , women; £1,878.6,  $p < 0.0001$ ). Also, mean medical expenditure in the year of death for participants who walked  $\geq 1$  hour per day was £16,878.6 in men and £17,464.3 in women, which was not significantly different from those who walked  $< 1$  hour per day (men; £16,650.0,  $p = 0.7315$ , women; £17,742.9,  $p = 0.8330$ ).

Baseline characteristics in terms of categories for time spent walking

Table 1 shows the baseline characteristics of the study participants according to the categories of time spent walking for men and women, respectively.

As compared with those who walked  $< 1$  hour per day, participants who walked  $\geq 1$  hour per day were less likely to be smokers and obese. Self-reported history of hypertension, diabetes mellitus, and liver disease were all significantly less prevalent in those who walked  $\geq 1$  hour per day.

### **Mortality in terms of categories for time spent walking**

Figure 1-a for men and Figure 1-b for women show the multiadjusted mortality (per 1,000) in each of the age-groups according to the categories of time spent walking.

In men in each age-group, multiadjusted mortality was lower in participants who walked  $\geq 1$  hour per day than in those who walked  $< 1$  hour per day. In women in all age-groups except for the aged 40-44 and 45-49 year groups, multiadjusted mortality was lower in participants who walked  $\geq 1$  hour per day than in those who walked  $< 1$  hour per day.

Table 2 shows the mortality ratio with 95% CIs according to the categories of time spent walking. In men, the multiadjusted mortality ratio for participants who walked  $\geq 1$  hour per day was significantly lower than that for participants who walked  $< 1$  hour per day (0.90, 95% CIs; 0.82-0.98,  $p=0.0153$ ). In women, the multiadjusted mortality ratio for participants who walked  $\geq 1$  hour per day was non-significantly lower than that for participants who walked  $< 1$  hour per day (0.95, 95% CIs; 0.82-1.10,  $p=0.4693$ ).

### **Life expectancy and lifetime medical expenditure in terms of time spent walking**

Table 3 shows life expectancy and lifetime medical expenditure with 95% CIs according to the categories of time spent walking.

As compared with those who walked <1 hour per day, men who walked  $\geq 1$  hour per day lived significantly longer, but their lifetime medical expenditure was significantly lower. The same results were observed for women, although the differences did not reach statistical significance.

In men, the multiadjusted life expectancy of those who walked  $\geq 1$  hour per day was 44.81 years (95% CI; 43.66-45.94), which was significantly longer by 1.38 years ( $p=0.0073$ ) than for those who walked <1 hour per day (43.43 years; 95% CI; 42.39-44.41). The multiadjusted lifetime medical expenditure for participants who walked  $\geq 1$  hour per day was £99,423.6 (95% CI; 92,515.9-106,694.7), being significantly lower by 7.6% ( $p=0.0048$ ) than for those who walked <1 hour per day (£107,544.2; 95% CI; 101,234.0-114,044.6).

In women, the multiadjusted life expectancy for participants who walked  $\geq 1$  hour per day was 57.78 years (95% CI; 54.02-62.22), which was non-significantly longer by 1.16 years ( $p=0.2351$ ) than for those who walked <1 hour per day (56.62 years; 95% CI; 53.17-60.62). The multiadjusted lifetime medical expenditure for participants who walked  $\geq 1$  hour per day was £128,161.2 (95% CI; 111,335.0-148,494.7), being non-significantly lower by 2.7% ( $p=0.2559$ ) than for those who walked <1 hour per day (£131,766.8; 95% CI; 115,902.4-150,714.3).

## DISCUSSION

The present results indicate that multiadjusted lifetime medical expenditure from the age of 40 years for those who walked  $\geq 1$  hour per day was lower by 7.6% in men and by 2.7% in women than for those who walked  $< 1$  hour per day. This decrease in lifetime medical expenditure was observed in spite of longer life expectancy (1.38 years for men and 1.16 years for women) among those who walked  $\geq 1$  hour per day. Thus, a healthy lifestyle not only extended longevity, but also decreased the amount of lifetime medical expenditure.

### Comparison with other studies

Four studies have addressed the association between physical activity level and life expectancy.<sup>1-4</sup> Additionally, studies investigating associations between time spent walking,<sup>5-13</sup> or distance walked<sup>17, 18</sup> and mortality have consistently shown that participants who have higher physical activity have longer life expectancy and lower mortality than participants who have lower physical activity. Only one study has reported the association between physical activity and lifetime medical expenditure.<sup>4</sup> In a simulation study, Keeler et al. demonstrated that if participants with a sedentary life style had exercised regularly, the additional exercise would have increased their life

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7 expectancy by 300 days and saved £1,900 in lifetime costs. Even though there is a  
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9 difference between physical activity and walking, this result is consistent with the  
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11 present finding that participants who walked  $\geq 1$  hour per day lived longer and had lower  
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13 lifetime medical expenditure.  
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17 We previously calculated life expectancy and lifetime medical expenditure in  
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19 relation to smoking and BMI from age 40 years using the same dataset as that for the  
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21 present study.<sup>23, 25</sup> The results indicated that lifetime medical expenditure was lower  
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23 for smokers than for non-smokers, reflecting the 3.5-year shorter life expectancy of  
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25 smokers.<sup>25</sup> On the other hand, lifetime medical expenditure was higher for  
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27 participants who were obese ( $BMI \geq 30.0$ ) than for those who had normal weight  
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29 ( $18.5 \leq BMI < 25.0$ ), even though the former lived 2.0 years less than the latter.<sup>23</sup> In fact,  
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31 both smokers and obese participants had shorter life expectancy than non-smokers and  
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33 normal-weight participants, whereas their lifetime medical expenditure was conversely  
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35 increased. These differences could be explained by the impact of these risk factors on  
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37 quality of life. Using prospective data for 16,176 adult Caucasians in the USA,<sup>32</sup>  
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39 Reuser et al. estimated life expectancy and years of life with and without activities of  
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41 daily living (ADL) disability in relation to smoking and BMI, respectively. The results  
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43 indicated that smoking decreased both life expectancy and years of life with ADL  
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45 disability, whereas obesity decreased the former but increased the latter, leading to their  
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47 conclusion that “smoking kills, and obesity disables”. Reuser’s conclusion is  
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concordant with the impact of walking on life expectancy and lifetime medical expenditure. Physical activity decreases not only mortality but also disability,<sup>5-13, 17, 18, 33</sup> leading to lower medical expenditure.<sup>34</sup> For instance, walking has been significantly associated with a lower risk of cardiovascular disease,<sup>7</sup> stroke,<sup>35</sup> coronary heart disease,<sup>36, 37</sup> type 2 diabetes,<sup>38</sup> and hypertension.<sup>39</sup> Consequently, walking also reduces expenditure on medication needed for these conditions.<sup>40</sup>

### Strengths and limitations

This is the first study to have investigated the association between walking, life expectancy, and lifetime medical expenditure. A major strength of this study was that we collected individual data on medical expenditure based on a cohort study of survival and medical care utilization, and its cost, for all participants,<sup>19, 22, 23, 25, 29</sup> and the NHI covers almost all medical treatment in Japan. Second, we conducted a 13-year prospective observation of 27,738 Japanese adults aged 40-79 years living in the community who were free of any functional limitations or chronic conditions interfering with physical activity, with an accrued total of 285,342 person-years. Third, in order to reduce bias or reverse causation in that people did not walk because of functional limitations that also required medical expenditure, we excluded participants who, at the baseline, reported limited physical function or conditions interfering with physical activity. Additionally, to control for confounders, we also included various covariates

in our Poisson regression model and linear regression model.

On the other hand, several limitations should also be considered. First, we assessed walking using a simple questionnaire in which we asked the participants to report only the time spent walking and did not ask about walking pace, distance walked, or any distinction between walking for exercise and other reasons. Second, longer time spent walking may be a reflection of performing more vigorous activity, making it difficult to distinguish the impact of walking from other types of physical activity. However, the present result did not change after multivariate adjustment.

**Conclusions and policy implication**

In summary, lifetime medical expenditure was shown to be decreased in participants who walked  $\geq 1$  hour per day, despite the fact that they lived longer. Increased longevity resulting from a healthier lifestyle did not necessarily translate into an increased amount of medical expenditure throughout life. Intervention aimed at encouraging people to walk may extend life expectancy without apparently increasing lifetime medical expenditure.

## Article focus

- Medical expenditure per month was reduced when time spent walking was increased.
- Walking is associated with a decreased risk of mortality.
- In view of the increased life expectancy of those who walk longer, it is unclear whether lifetime medical expenditure increases or decreases as a result.

## Key messages

- Lifetime medical expenditure from the age of 40 years for men and women who walked  $\geq 1$  hour per day was reduced by 7.6% and 2.7%, respectively, in comparison with those who walked  $< 1$  hour per day.
- Years of life added as a result of a healthy lifestyle did not necessarily translate into an increased amount of lifetime medical expenditure.

## Strengths and limitations of this study

- This is the first study to have investigated the association between walking, life expectancy, and lifetime medical expenditure.
- We assessed walking using a simple questionnaire in which we asked the participants to report only the time spent walking and did not ask about walking pace, distance

walked, or any distinction between walking for exercise and other reasons.

**Contributions**

All authors contributed to the design of the study. Masato Nagai, Shinichi Kuriyama, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, and Ichiro Tsuji participated in data collection. Masato Nagai, Shinichi Kuriyama, Atsushi Hozawa, Miyuki Kawado and Shuji Hashimoto participated in data analysis. Masato Nagai, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, Atsushi Hozawa, Miyuki Kawad, and Shuji Hashimoto participated in the writing of the report. Shinichi Kuriyama and Ichiro Tsuji participated in critical revision of the manuscript. All authors approved the final version of the report for submission.

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**Conflicts of Interest**

The authors declare that they have no conflicts of interest.

### **Ethical approval**

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

### **Data sharing**

No additional data available.

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### **Figure legend**

Figure 1

Multiadjusted mortality by the categories of time spent walking in each age-groups in

men (a) and women (b).

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Table 1. Baseline characteristics by time spent walking categories in 27,738 participants

|                                  | Men                |         |                      | Women              |         |                      |
|----------------------------------|--------------------|---------|----------------------|--------------------|---------|----------------------|
|                                  | Time spent walking |         | p value <sup>†</sup> | Time spent walking |         | p value <sup>†</sup> |
|                                  | <1 hour            | ≥1 hour |                      | <1 hour            | ≥1 hour |                      |
| No. of subjects                  | 7,363              | 8,158   |                      | 6,303              | 5,914   |                      |
| Smoking status (%)               |                    |         |                      |                    |         |                      |
| Current and Past smoker          | 81.9               | 79.8    | 0.0011               | 12.6               | 9.9     | <0.0001              |
| Never smoker                     | 18.1               | 20.2    |                      | 87.5               | 90.1    |                      |
| Alcohol drinking (%)             |                    |         |                      |                    |         |                      |
| Never and past drinker           | 26.5               | 25.1    | 0.1117               | 74.7               | 75.4    | 0.1380               |
| Current drinker, 1-449 g/wee     | 61.3               | 62.2    |                      | 24.3               | 23.9    |                      |
| Current drinker, ≥450 g/weel     | 12.2               | 12.8    |                      | 1.1                | 0.7     |                      |
| Body mass index (%)              |                    |         |                      |                    |         |                      |
| <21 kg/m <sup>2</sup>            | 18.5               | 20.5    | <0.0001              | 18.6               | 19.4    | 0.0019               |
| 21-24.9 kg/m <sup>2</sup>        | 53.3               | 55.8    |                      | 50.7               | 52.9    |                      |
| ≥25 kg/m <sup>2</sup>            | 28.3               | 23.7    |                      | 30.7               | 27.7    |                      |
| Self-rated health (%)            |                    |         |                      |                    |         |                      |
| Good                             | 73.1               | 79.3    | <0.0001              | 72.5               | 78.2    | <0.0001              |
| Not good                         | 26.9               | 20.7    |                      | 27.5               | 21.8    |                      |
| Sports and physical activity (%) |                    |         |                      |                    |         |                      |
| ≥3 hours/week                    | 13.2               | 18.7    | <0.0001              | 10.7               | 16.6    | <0.0001              |
| <3 hours/week                    | 86.8               | 81.3    |                      | 89.3               | 83.4    |                      |
| History of hypertension (%)      |                    |         |                      |                    |         |                      |
| Presence                         | 21.5               | 18.6    | <0.0001              | 24.2               | 20.1    | <0.0001              |
| Absence                          | 78.5               | 81.4    |                      | 75.8               | 79.9    |                      |
| History of diabetes mellitus (%) |                    |         |                      |                    |         |                      |
| Presence                         | 7.4                | 4.8     | <0.0001              | 5.1                | 3.2     | <0.0001              |
| Absence                          | 92.6               | 95.2    |                      | 94.9               | 96.8    |                      |
| History of cancer (%)            |                    |         |                      |                    |         |                      |
| Presence                         | 2.1                | 1.8     | 0.2563               | 2.8                | 2.8     | 0.9032               |
| Absence                          | 97.9               | 98.2    |                      | 97.2               | 97.2    |                      |
| History of liver disease (%)     |                    |         |                      |                    |         |                      |
| Presence                         | 6.9                | 5.7     | 0.0013               | 3.7                | 2.9     | 0.0223               |
| Absence                          | 93.1               | 94.4    |                      | 96.3               | 97.1    |                      |
| History of kidney disease (%)    |                    |         |                      |                    |         |                      |
| Presence                         | 2.9                | 2.7     | 0.3493               | 3.6                | 2.7     | 0.0049               |
| Absence                          | 97.1               | 97.3    |                      | 96.4               | 97.3    |                      |

<sup>†</sup> p values were calculated by chi-squared test.

Table 2. Mortality ratio for time spent walking categories in 27,738 participants.

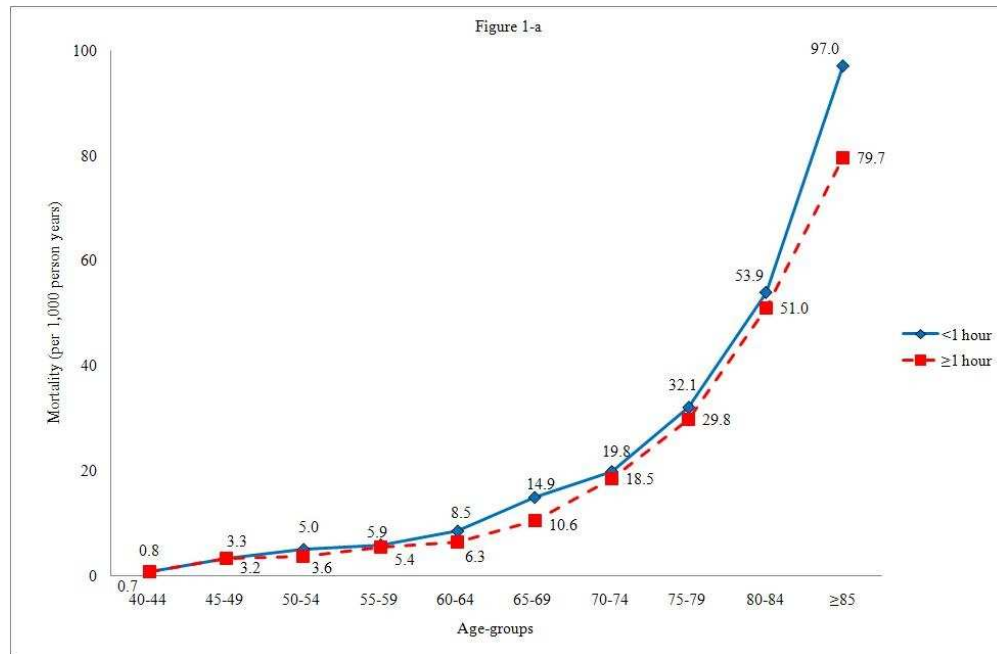
|       | Time spent walking | Univariate      |                         |                | Multiadjusted <sup>†</sup> |                         |                |
|-------|--------------------|-----------------|-------------------------|----------------|----------------------------|-------------------------|----------------|
|       |                    | Mortality ratio | 95% confidence interval | <i>p</i> value | Mortality ratio            | 95% confidence interval | <i>p</i> value |
| Men   | <1 hour            | 1.00            |                         |                | 1.00                       |                         |                |
|       | ≥1 hour            | 0.87            | 0.80 - 0.94             | 0.0009         | 0.90                       | 0.82 - 0.98             | 0.0153         |
| Women | <1 hour            | 1.00            |                         |                | 1.00                       |                         |                |
|       | ≥1 hour            | 0.89            | 0.77 - 1.03             | 0.1135         | 0.95                       | 0.82 - 1.10             | 0.4693         |

<sup>†</sup> Adjusted for age groups, smoking status, alcohol drinking, body mass index, self-rated health, sports and physical activity, and history of hypertension disease, diabetes mellitus, cancer, liver disease and kidney disease.

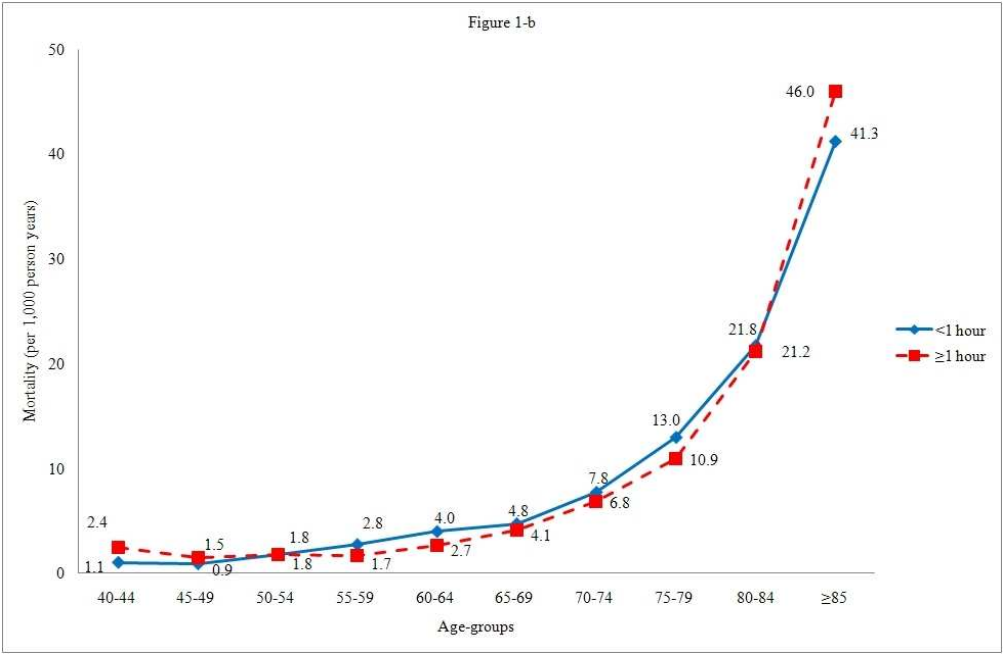
Table 3. Life expectancy and lifetime medical expenditure at age 40 years for time spent walking categories in 27,738 participants.

|       | Time spent walking                               | Univariate |                         |                | Multiadjusted <sup>†</sup> |                         |                |
|-------|--|------------|-------------------------|----------------|----------------------------|-------------------------|----------------|
|       |  | Estimate   | 95% confidence interval | <i>p</i> value | Estimate                   | 95% confidence interval | <i>p</i> value |
| Men   | Life expectancy at age 40 years (years)          |            |                         |                |                            |                         |                |
|       | <1 hour  | 42.41      | 41.45 - 43.26           |                | 43.43                      | 42.39 - 44.41           |                |
|       | ≥1 hour  | 44.19      | 43.15 - 45.19           | 0.0004         | 44.81                      | 43.66 - 45.94           | 0.0073         |
|       | Lifetime medical expenditure at age 40 years (£) |            |                         |                |                            |                         |                |
|       | <1 hour  | 107,023.2  | 101,093.6 - 113,066.3   |                | 107,544.2                  | 101,234.0 - 114,044.6   |                |
|       | ≥1 hour  | 94,402.1   | 87,812.3 - 101,248.0    | <0.0001        | 99,423.6                   | 92,515.9 - 106,694.7    | 0.0048         |
| Women | Life expectancy at age 40 years (years)          |            |                         |                |                            |                         |                |
|       | <1 hour  | 52.25      | 49.79 - 54.92           |                | 56.62                      | 53.17 - 60.62           | 0.2351         |
|       | ≥1 hour  | 54.25      | 51.38 - 57.48           | 0.0569         | 57.78                      | 54.02 - 62.22           |                |
|       | Lifetime medical expenditure at age 40 years (£) |            |                         |                |                            |                         |                |
|       | <1 hour  | 123,553.0  | 111,619.5 - 137,549.6   |                | 131,766.8                  | 115,902.4 - 150,714.3   |                |
|       | ≥1 hour  | 115,896.0  | 102,406.6 - 131,792.1   | 0.0644         | 128,161.2                  | 111,335.0 - 148,494.7   | 0.2559         |

<sup>†</sup> Adjusted for age groups, smoking status, alcohol drinking, body mass index, self-rated health, sports and physical activity, and history of hypertension disease, diabetes mellitus, cancer, liver disease and kidney disease.



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

| Section/Topic             | Item # | Recommendation   | Reported on page # |
|---------------------------|--------|--|--------------------|
| Title and abstract        | 1      | (a) Indicate the study’s design with a commonly used term in the title or the abstract   | p. 1, 3            |
|                           |        | (b) Provide in the abstract an informative and balanced summary of what was done and what was found  | p. 3, 4            |
| Introduction              |        |  |                    |
| Background/rationale      | 2      | Explain the scientific background and rationale for the investigation being reported   | p. 5               |
| Objectives                | 3      | State specific objectives, including any prespecified hypotheses   | p. 5, 6            |
| Methods                   |        |  |                    |
| Study design              | 4      | Present key elements of study design early in the paper  | p. 6               |
| Setting                   | 5      | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  | p. 7-9             |
| Participants              | 6      | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up   | p. 7-8             |
|                           |        | (b) For matched studies, give matching criteria and number of exposed and unexposed  |                    |
| Variables                 | 7      | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable   | p. 8-11            |
| Data sources/ measurement | 8*     | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | p. 8-11            |
| Bias                      | 9      | Describe any efforts to address potential sources of bias  | p. 10              |
| Study size                | 10     | Explain how the study size was arrived at  | p. 8               |
| Quantitative variables    | 11     | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why   | p. 10              |
| Statistical methods       | 12     | (a) Describe all statistical methods, including those used to control for confounding  | p. 9-11            |
|                           |        | (b) Describe any methods used to examine subgroups and interactions  | -                  |
|                           |        | (c) Explain how missing data were addressed  | -                  |
|                           |        | (d) If applicable, explain how loss to follow-up was addressed   | p. 8, 9            |
|                           |        | (e) Describe any sensitivity analyses  | p. 9-11-           |
| Results                   |        |  |                    |

|                   |     |  |           |
|-------------------|-----|--|-----------|
| Participants      | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed            | p. 7, 8   |
|                   |     | (b) Give reasons for non-participation at each stage   | p. 7, 8   |
|                   |     | (c) Consider use of a flow diagram   | -         |
| Descriptive data  | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders   | p. 12     |
|                   |     | (b) Indicate number of participants with missing data for each variable of interest  | -         |
|                   |     | (c) Summarise follow-up time (eg, average and total amount)  | p. 12     |
| Outcome data      | 15* | Report numbers of outcome events or summary measures over time   | -         |
| Main results      | 16  | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | p. 13, 14 |
|                   |     | (b) Report category boundaries when continuous variables were categorized  | p. 8, 10  |
|                   |     | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period   | -         |
| Other analyses    | 17  | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses   | -         |
| Discussion        |     |  |           |
| Key results       | 18  | Summarise key results with reference to study objectives   | p. 15     |
| Limitations       |     |  |           |
| Interpretation    | 20  | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence                                   | p. 15-18  |
| Generalisability  | 21  | Discuss the generalisability (external validity) of the study results  | p. 17     |
| Other information |     |  |           |
| Funding           | 22  | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based  | p. 20     |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).



## Impact of Walking on Life Expectancy and Lifetime Medical Expenditure: The Ohsaki Cohort Study

|                                 |  |
|---------------------------------|--|
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| <b>Primary Subject Heading</b>: | Epidemiology   |
| Keywords:                       | walking, lifetime medical expenditure, life expectancy, physical activity  |
|                                 |  |

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**Research**

**Impact of Walking on Life Expectancy and Lifetime Medical Expenditure: The  
Ohsaki Cohort Study**

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**Abstract**

**Objective**

People who spend a longer time walking have lower demands for medical care. However, in view of their longer life expectancy, it is unclear whether their lifetime medical expenditure increases or decreases. The present study examined the association between time spent walking, life expectancy, and lifetime medical expenditure.

**Method**

We followed up 27,738 participants aged 40-79 years and prospectively collected data on their medical expenditure and survival covering a 13-year period. Participants were classified into those walking <1 and  $\geq 1$  hour per day. We constructed life tables, and estimated the life expectancy and lifetime medical expenditure from 40 years of age using estimate of multiadjusted mortality and medical expenditure by Poisson regression model and linear regression model, respectively.

**Results**

Participants who walked  $\geq 1$  hour per day have longer life expectancy from 40 years of age than participants who walked <1 hour per day. The multiadjusted life expectancy for those who walked  $\geq 1$  hour per day was 44.81 years, being significantly lower by 1.38 years in men ( $p=0.0073$ ) in men and 57.78 years in women, being non-significantly lower by 1.16 years in women ( $p=0.2351$ ). In spite of their longer life expectancy, participants who walked  $\geq 1$  hour per day required lower lifetime medical expenditure from 40 years

of age than participants who walked <1 hour per day. The multiadjusted lifetime medical expenditure for those who walked  $\geq 1$  hour per day was £99,423.6, being significantly lower by 7.6% in men ( $p=0.0048$ ) and £128,161.2, being non-significantly lower by 2.7% in women ( $p=0.2559$ ).

## Discussion

Increased longevity resulting from a healthier lifestyle does not necessarily translate into an increased amount of medical expenditure throughout life. Encouraging people to walk may extend life expectancy and decrease lifetime medical expenditure, especially men.

(285 words)

## Key Words:

walking; lifetime medical expenditure; life expectancy; physical activity;

## INTRODUCTION

Previous studies have agreed that a higher level of physical activity extends life

expectancy.<sup>1-4</sup> Walking is part of a physically active lifestyle. Previous studies have indicated that a longer time spent walking,<sup>5-13</sup> walking pace,<sup>8, 14-16</sup> and a longer distance walked<sup>17, 18</sup> are significantly associated with a decreased risk of mortality.

We previously reported that medical expenditure per month was significantly reduced among those who spent a longer time walking, based on the same cohort dataset as that used here.<sup>19</sup> Similar findings have been reported worldwide.<sup>20, 21</sup> However, in view of the increased life expectancy of those who walk for a longer time, it is unclear whether lifetime medical expenditure increases or decreases as a result. In other words, the question to be answered here is whether a lifelong healthy lifestyle eventually increases lifetime medical expenditure because of extended life expectancy.

So far, only one study has examined the association between physical activity and lifetime costs.<sup>4</sup> This revealed that people with a high physical activity level tended to live longer than people with a lower physical activity level, and that the former had lower lifetime medical costs than the latter. However, that study was only a simulation analysis based on assumed variations in the health and economic effects of active and sedentary lifestyles.

The objective of the present study was to examine the association between walking, life expectancy, and lifetime medical expenditure using actual individual data derived from a population-based 13-year prospective observation period. The population comprised 27,738 Japanese adults aged 40-79 years living in the community who were

free of any functional limitations or chronic conditions interfering with physical activity, with an accrued total of 285,342 person-years. This cohort study has been monitoring survival and medical care utilization, and its costs, for all participants.<sup>19, 22, 23</sup> Using this dataset, we constructed a life table to estimate life expectancy and lifetime medical expenditure according to the time spent walking.<sup>23-25</sup>

## MATERIALS AND METHODS

**Study cohort**

The present data were derived from the Ohsaki National Health Insurance (NHI) Cohort Study.<sup>19, 22, 23, 26</sup> We conducted a self-administered questionnaire survey of various lifestyle habits between October and December 1994 for all NHI beneficiaries aged 40 to 79 years who lived in the catchment area of Ohsaki Public Health Center, Miyagi Prefecture, northeastern Japan. Out of 54,996 eligible individuals, 52,029 (95%) responded.

We excluded 776 participants who had withdrawn from the NHI before January 1, 1995 because their cost data were not available. Thus, the remaining 51,253 participants formed the study cohort. The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

For the present analysis, we excluded participants who had functional limitation or chronic conditions interfering with physical activity. Physical function status was assessed using the 6-item measure of the Medical Outcomes Study (MOS) Short-form General Health Survey.<sup>27</sup> Participants were excluded if they stated on the MOS questionnaire that they were unable to perform moderate or vigorous activities (n=15,916). We excluded participants who reported severe bodily pain (n=949), or history of stroke (n=474), myocardial infarction (n=585) or arthritis (n=2,176). We also

excluded those who died within the first year (n=174) or did not provide complete responses in the walking status questionnaire (n=3,241). Thus, a total of 27,738 participants (15,521 men and 12,217 women) remained. These participants were apparently healthy enough to walk for as long as they wished.

### Time spent walking

The self-administered questionnaire included items on time spent walking. Time spent walking was assessed through the subject's response to the question, "About how much time do you walk per day on average?". The participants were asked to choose one of three answers: "1 hour or more" "30 minutes - 1 hour" or "30 minutes or less". In Japan, the Ministry of Health, Labour and Welfare recommended to walk  $\geq 1$  hour per day in Exercise and Physical Activity Reference for Health Promotion 2006. Then, we divided the participants into two groups according to the time spent walking daily:  $< 1$  hour and  $\geq 1$  hour. We had previously evaluated and reported the validity of self-reported time spent walking.<sup>5, 19, 28</sup> This validation study had indicated that self-reported walking time was reasonably reproducible and sufficiently valid for studying the health effects of walking.

### Health insurance system in Japan

Details of the Japanese NHI system have been described previously.<sup>22, 23, 29, 30</sup> Briefly, everyone living in Japan is required to enroll in a health insurance system. The NHI

covers 35% of the Japanese population, mainly farmers, self employed, or retired people. The NHI covers almost all medical treatment, including diagnostic tests, medication, surgery, supplies and materials, physicians and other personnel costs, inpatient care, and most dental treatment. It covers treatment by physicians and nurses but not that by other professionals such as home health aides. Payment to medical providers is made on a fee-for-service basis, where the price of each service is determined by a uniform national fee schedule.

When a participant withdraws from the NHI system because of death, emigration, or employment, the withdrawal date and its reason are coded in the NHI withdrawal history files. We recorded any mortality or migration by reviewing the NHI withdrawal history files and collected data on the death of participants by reviewing the death certificates filed at Ohsaki Public Health Center. We thus followed up the participants and prospectively collected data on medical care utilization and its costs for all individuals in the cohort from January 1 1995 through December 31 2007. Study participants (16.3%) were lost to follow-up, thus their vital status was unknown.

**Statistical analysis**

Using the Ohsaki NHI cohort database, we estimated mortality and medical expenditure for individual age-groups, and for the categories of time spent walking, for both men and

women. We divided age in to the following groups: 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, and  $\geq 85$  years. The multiadjusted mortality rates for each age category were estimated from a Poisson regression model based on person-years and the number of deaths from 1996 until 2007. The dependent variable was mortality and independent variables were age-groups, categories of time spent walking, and the following covariates: smoking status (current and past smoker, or never smoker), alcohol consumption (current drinker consuming 1-499 g/week, current drinker consuming  $\geq 450$  g/week, or never and past drinker), body mass index (BMI:  $<21$  kg/m<sup>2</sup>, 21-24.9 kg/m<sup>2</sup>, or  $\geq 25$  kg/m<sup>2</sup>), self-rated health (good or not good), sports and physical activity ( $\geq 3$  hours/week or  $<3$  hours/week), history of hypertension disease (presence or absence), history of diabetes mellitus (presence or absence), history of cancer (presence or absence), history of liver disease (presence or absence), and history of kidney disease (presence or absence).<sup>19</sup> The data of all covariates was obtained from self-administered questionnaire. We estimated the mortality of participants aged  $\geq 85$  years by multiplying the estimated mortality for the 85-89 year age-group by the ratio of mortality for the same age-group relative to the mortality for  $\geq 85$  years from complete life tables for the year 2000, as there were few person-years for participants aged over 90 years in our dataset.<sup>31</sup>

Because medical expenditure increases before death, we separately calculated medical expenditure for participants who survived through the index year and for those who died. The multiadjusted medical expenditure per year for survivors and decedents, respectively,

was estimated for each of the age-groups and the categories of time spent walking using a linear regression model adjusted for the above covariates.

The estimates of multiadjusted mortality and medical expenditure for each age-group were used for estimating life expectancy and lifetime medical expenditure from 40 years of age. Life expectancy was calculated using Chiang’s analytical method on the basis of the latest published complete life tables of Japan for the year 2000.<sup>23, 24, 31</sup> Lifetime medical expenditure was estimated from the sum obtained by multiplying the static population in life table by the medical expenditure for survivors and the number of deaths in the life table by the increased medical expenditure due to death, which was calculated by subtracting the medical expenditure in year of survivors from that in the period of 1 year before death. That is, life expectancy ( $e_x$ ) and lifetime medical expenditure ( $M_x$ ) for each age-groups (x) were estimated using the numbers of survivors ( $l_x$ ), deaths ( $d_x$ ), static population ( $L_x$ ), multiadjusted medical expenditure for survivors ( $a_y$ ), and multiadjusted medical expenditure for the deceased ( $b_y$ ) as follows;

$\sum_{y \geq x}$  is sum of  $y \geq x$

$$e_x = \frac{\sum L_y}{l_x}$$

$$M_x = \frac{\sum (L_y \cdot a_y + d_y \cdot b_y)}{l_x}$$

The 95% confidence intervals (CIs) were estimated using a Monte Carlo simulation based on a Poisson regression model and linear regression model. We repeated 100,000

times and all analysis were used the SAS version 9.1 statistical software package (SAS Institute Inc., 2004).

We used a purchasing power parity rate of UK£ 1.00=JP¥ 140.

## RESULTS

After 13 years of follow-up, we observed 2,936 deaths (2,193 men and 743 women) among the 27,738 participants (15,521 men and 12,217 women). Mean medical

expenditure per year for survivors who walked  $\geq 1$  hour per day was £1,714.2 in men and £1,621.4 in women, being significantly lower than for those who walked  $< 1$  hour per day (men; £2,064.3,  $p < 0.0001$ , women; £1,878.6,  $p < 0.0001$ ). Also, mean medical expenditure in the year of death for participants who walked  $\geq 1$  hour per day was £16,878.6 in men and £17,464.3 in women, which was not significantly different from those who walked  $< 1$  hour per day (men; £16,650.0,  $p = 0.7315$ , women; £17,742.9,  $p = 0.8330$ ).

**Baseline characteristics in terms of categories for time spent walking**

Table 1 shows the baseline characteristics of the study participants according to the categories of time spent walking for men and women, respectively.

As compared with those who walked  $< 1$  hour per day, participants who walked  $\geq 1$  hour per day were less likely to be smokers and obese. Self-reported history of hypertension, diabetes mellitus, and liver disease were all significantly less prevalent in those who walked  $\geq 1$  hour per day.

**Mortality in terms of categories for time spent walking**

Figure 1-a for men and Figure 1-b for women show the multiadjusted mortality (per 1,000) in each of the age-groups according to the categories of time spent walking.

In men in each age-group, multiadjusted mortality was lower in participants who walked  $\geq 1$  hour per day than in those who walked  $< 1$  hour per day. In women in all age-groups except for the aged 40-44 and 45-49 year groups, multiadjusted mortality was lower in participants who walked  $\geq 1$  hour per day than in those who walked  $< 1$  hour per day.

Table 2 shows the mortality ratio with 95% CIs according to the categories of time spent walking. In men, the multiadjusted mortality ratio for participants who walked  $\geq 1$  hour per day was significantly lower than that for participants who walked  $< 1$  hour per day (0.90, 95% CIs; 0.82-0.98,  $p=0.0153$ ). In women, the multiadjusted mortality ratio for participants who walked  $\geq 1$  hour per day was non-significantly lower than that for participants who walked  $< 1$  hour per day (0.95, 95% CIs; 0.82-1.10,  $p=0.4693$ ).

### **Life expectancy and lifetime medical expenditure in terms of time spent walking**

Table 3 shows life expectancy and lifetime medical expenditure from 40 years of age with 95% CIs according to the categories of time spent walking.

In men, the multiadjusted life expectancy of those who walked  $\geq 1$  hour per day was 44.81 years (95% CI; 43.66-45.94), which was significantly longer by 1.38 years ( $p=0.0073$ ) than for those who walked  $< 1$  hour per day (43.43 years; 95% CI; 42.39-44.41). In women, the same results were observed, although the differences did not reach statistical significance.

In spite of their longer life expectancy, their lifetime medical expenditure from 40 years of age was significantly lower in men and non-significantly lower in women. The multiadjusted lifetime medical expenditure for participants who walked  $\geq 1$  hour per day was £99,423.6 (95% CI; 92,515.9-106,694.7), being significantly lower by 7.6% ( $p=0.0048$ ) than for those who walked  $<1$  hour per day (£107,544.2; 95% CI; 101,234.0-114,044.6). In women, the multiadjusted lifetime medical expenditure for participants who walked  $\geq 1$  hour per day was £128,161.2 (95% CI; 111,335.0-148,494.7), being non-significantly lower by 2.7% ( $p=0.2559$ ) than for those who walked  $<1$  hour per day (£131,766.8; 95% CI; 115,902.4-150,714.3).

DISCUSSION

The present results indicate that multiadjusted lifetime medical expenditure from the age of 40 years for those who walked  $\geq 1$  hour per day was significantly lower by 7.6% in men

and non-significantly lower by 2.7% in women than for those who walked <1 hour per day. This decrease in lifetime medical expenditure was observed in spite of longer life expectancy (1.38 years for men and 1.16 years for women) among those who walked  $\geq 1$  hour per day. Thus, a healthy lifestyle not only extended longevity, but also decreased the amount of lifetime medical expenditure, especially men.

We observed statistically significant differences for men but not for women.

Although the differences did not reach statistical significance, the same results were observed for women. The reason why the impact of walking was smaller in women than in men was unknown. In women, other factors such as obesity and postmenopausal change might have stronger impact on life expectancy and lifetime medical expenditure than walking.

### Comparison with other studies

Four studies have addressed the association between physical activity level and life expectancy.<sup>1-4</sup> Additionally, studies investigating associations between time spent walking,<sup>5-13</sup> or distance walked<sup>17, 18</sup> and mortality have consistently shown that participants who have higher physical activity have longer life expectancy and lower mortality than participants who have lower physical activity. Only one study has reported the association between physical activity and lifetime medical expenditure.<sup>4</sup> In a simulation study, Keeler et al. demonstrated that if participants with a sedentary life style

had exercised regularly, the additional exercise would have increased their life expectancy by 300 days and saved £1,900 in lifetime costs. Even though there is a difference between physical activity and walking, this result is consistent with the present finding that participants who walked  $\geq 1$  hour per day lived longer and had lower lifetime medical expenditure.

We previously calculated life expectancy and lifetime medical expenditure in relation to smoking and BMI from age 40 years using the same dataset as that for the present study.<sup>23, 25</sup> The results indicated that lifetime medical expenditure was lower for smokers than for non-smokers, reflecting the 3.5-year shorter life expectancy of smokers.<sup>25</sup> On the other hand, lifetime medical expenditure was higher for participants who were obese ( $BMI \geq 30.0$ ) than for those who had normal weight ( $18.5 \leq BMI < 25.0$ ), even though the former lived 2.0 years less than the latter.<sup>23</sup> In fact, both smokers and obese participants had shorter life expectancy than non-smokers and normal-weight participants, whereas their lifetime medical expenditure was conversely increased. These differences could be explained by the impact of these risk factors on quality of life. Using prospective data for 16,176 adult Caucasians in the USA,<sup>32</sup> Reuser et al. estimated life expectancy and years of life with and without activities of daily living (ADL) disability in relation to smoking and BMI, respectively. The results indicated that smoking decreased both life expectancy and years of life with ADL disability, whereas obesity decreased the former but increased the latter, leading to their conclusion that “smoking kills, and obesity disables”. Reuser’s

conclusion is concordant with the impact of walking on life expectancy and lifetime medical expenditure. Physical activity decreases not only mortality but also disability,<sup>5-13, 17, 18, 33</sup> leading to lower medical expenditure.<sup>34</sup> For instance, walking has been significantly associated with a lower risk of cardiovascular disease,<sup>7</sup> stroke,<sup>35</sup> coronary heart disease,<sup>36, 37</sup> type 2 diabetes,<sup>38</sup> and hypertension.<sup>39</sup> Consequently, walking also reduces expenditure on medication needed for these conditions.<sup>40</sup>

### Strengths and limitations

This is the first study to have investigated the association between walking, life expectancy, and lifetime medical expenditure. A major strength of this study was that we collected individual data on medical expenditure based on a cohort study of survival and medical care utilization, and its cost, for all participants,<sup>19, 22, 23, 25, 29</sup> and the NHI covers almost all medical treatment in Japan. Second, we conducted a 13-year prospective observation of 27,738 Japanese adults aged 40-79 years living in the community who were free of any functional limitations or chronic conditions interfering with physical activity, with an accrued total of 285,342 person-years. Third, in order to reduce bias or reverse causation in that people did not walk because of functional limitations that also required medical expenditure, we excluded participants who, at the baseline, reported limited physical function or conditions interfering with physical activity. Additionally, to control for confounders, we also included various covariates in our Poisson regression

model and linear regression model.

On the other hand, several limitations should also be considered. First, we assessed walking using a simple questionnaire in which we asked the participants to report only the time spent walking and did not ask about walking pace, distance walked, or any distinction between walking for exercise and other reasons. Second, longer time spent walking may be a reflection of performing more vigorous activity, making it difficult to distinguish the impact of walking from other types of physical activity. However, the present result did not change after multivariate adjustment.

**Conclusions and policy implication**

In summary, lifetime medical expenditure was shown to be decreased in participants who walked  $\geq 1$  hour per day, despite the fact that they lived longer. Increased longevity resulting from a healthier lifestyle did not necessarily translate into an increased amount of medical expenditure throughout life. However, in present study, around 50 % of study participants walks  $< 1$  hour per day. To increase their walking time, recommendation of walking with pedometer may be useful.<sup>41</sup> An increase in walking time at the population level would bring about a tremendous change in people’s health and medical cost. The campaign to encourage the people walk longer and program to make environment for people to walk more safely and pleasantly should be implemented. This intervention may extend life expectancy without apparently increasing lifetime medical expenditure,

especially men.

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#### Article focus

- Medical expenditure per month was reduced when time spent walking was increased.
- Walking is associated with a decreased risk of mortality.
- In view of the increased life expectancy of those who walk longer, it is unclear whether

lifetime medical expenditure increases or decreases as a result.

**Key messages**

- Lifetime medical expenditure from the age of 40 years for men and women who walked  $\geq 1$  hour per day was reduced by 7.6% and 2.7%, respectively, in comparison with those who walked  $< 1$  hour per day.
- Years of life added as a result of a healthy lifestyle did not necessarily translate into an increased amount of lifetime medical expenditure.

**Strengths and limitations of this study**

- This is the first study to have investigated the association between walking, life expectancy, and lifetime medical expenditure.
- We assessed walking using a simple questionnaire in which we asked the participants to report only the time spent walking and did not ask about walking pace, distance walked, or any distinction between walking for exercise and other reasons.

**Contributions**

All authors contributed to the design of the study. Masato Nagai, Shinichi Kuriyama, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, and Ichiro Tsuji participated in data collection. Masato Nagai, Shinichi Kuriyama, Atsushi Hozawa, Miyuki Kawado

and Shuji Hashimoto participated in data analysis. Masato Nagai, Masako Kakizaki, Kaori Ohmori-Matsuda, Toshimasa Sone, Atsushi Hozawa, Miyuki Kawad, and Shuji Hashimoto participated in the writing of the report. Shinichi Kuriyama and Ichiro Tsuji participated in critical revision of the manuscript. All authors approved the final version of the report for submission.

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### **Conflicts of Interest**

The authors declare that they have no conflicts of interest.

### **Ethical approval**

The study protocol was approved by the Ethics Committee of Tohoku University School of Medicine. Participants who had returned the self-administered questionnaires and signed them were considered to have consented to participate.

**Data sharing**

No additional data available.

**Figure legend**

Figure 1

Multiadjusted mortality by time spent walking categories in each age-groups in men (a) and women (b).

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Table 1. Baseline characteristics by time spent walking categories in 27,738 participants.

|                                  | Men                |         |                             | Women              |         |                             |
|----------------------------------|--------------------|---------|-----------------------------|--------------------|---------|-----------------------------|
|                                  | Time spent walking |         | <i>p</i> value <sup>†</sup> | Time spent walking |         | <i>p</i> value <sup>†</sup> |
|                                  | <1 hour            | ≥1 hour |                             | <1 hour            | ≥1 hour |                             |
| No. of subjects                  | 7,363              | 8,158   |                             | 6,303              | 5,914   |                             |
| Mean age                         | 57.4               | 57.2    | 0.2784                      | 57.9               | 57.6    | 0.0714                      |
| (Standard deviation)             | (10.6)             | (10.2)  |                             | (10.1)             | (9.7)   |                             |
| Smoking status (%)               |                    |         |                             |                    |         |                             |
| Current and Past smoker          | 81.9               | 79.8    | 0.0011                      | 12.6               | 9.9     | <0.0001                     |
| Never smoker                     | 18.1               | 20.2    |                             | 87.5               | 90.1    |                             |
| Alcohol drinking (%)             |                    |         |                             |                    |         |                             |
| Never and past drinker           | 26.5               | 25.1    | 0.1117                      | 74.7               | 75.4    | 0.1380                      |
| Current drinker, 1-449 g/week    | 61.3               | 62.2    |                             | 24.3               | 23.9    |                             |
| Current drinker, ≥450 g/week     | 12.2               | 12.8    |                             | 1.1                | 0.7     |                             |
| Body mass index (%)              |                    |         |                             |                    |         |                             |
| <21 kg/m <sup>2</sup>            | 18.5               | 20.5    | <0.0001                     | 18.6               | 19.4    | 0.0019                      |
| 21-24.9 kg/m <sup>2</sup>        | 53.3               | 55.8    |                             | 50.7               | 52.9    |                             |
| ≥25 kg/m <sup>2</sup>            | 28.3               | 23.7    |                             | 30.7               | 27.7    |                             |
| Self-rated health (%)            |                    |         |                             |                    |         |                             |
| Good                             | 73.1               | 79.3    | <0.0001                     | 72.5               | 78.2    | <0.0001                     |
| Not good                         | 26.9               | 20.7    |                             | 27.5               | 21.8    |                             |
| Sports and physical activity (%) |                    |         |                             |                    |         |                             |
| ≥3 hours/week                    | 13.2               | 18.7    | <0.0001                     | 10.7               | 16.6    | <0.0001                     |
| <3 hours/week                    | 86.8               | 81.3    |                             | 89.3               | 83.4    |                             |
| History of hypertension (%)      |                    |         |                             |                    |         |                             |
| Presence                         | 21.5               | 18.6    | <0.0001                     | 24.2               | 20.1    | <0.0001                     |
| Absence                          | 78.5               | 81.4    |                             | 75.8               | 79.9    |                             |
| History of diabetes mellitus (%) |                    |         |                             |                    |         |                             |
| Presence                         | 7.4                | 4.8     | <0.0001                     | 5.1                | 3.2     | <0.0001                     |
| Absence                          | 92.6               | 95.2    |                             | 94.9               | 96.8    |                             |
| History of cancer (%)            |                    |         |                             |                    |         |                             |
| Presence                         | 2.1                | 1.8     | 0.2563                      | 2.8                | 2.8     | 0.9032                      |
| Absence                          | 97.9               | 98.2    |                             | 97.2               | 97.2    |                             |
| History of liver disease (%)     |                    |         |                             |                    |         |                             |
| Presence                         | 6.9                | 5.7     | 0.0013                      | 3.7                | 2.9     | 0.0223                      |
| Absence                          | 93.1               | 94.4    |                             | 96.3               | 97.1    |                             |
| History of kidney disease (%)    |                    |         |                             |                    |         |                             |
| Presence                         | 2.9                | 2.7     | 0.3493                      | 3.6                | 2.7     | 0.0049                      |
| Absence                          | 97.1               | 97.3    |                             | 96.4               | 97.3    |                             |

<sup>†</sup> *p* values were calculated by t-test or chi-squared test.

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Table 2. Mortality ratio for time spent walking categories in 27,738 participants.

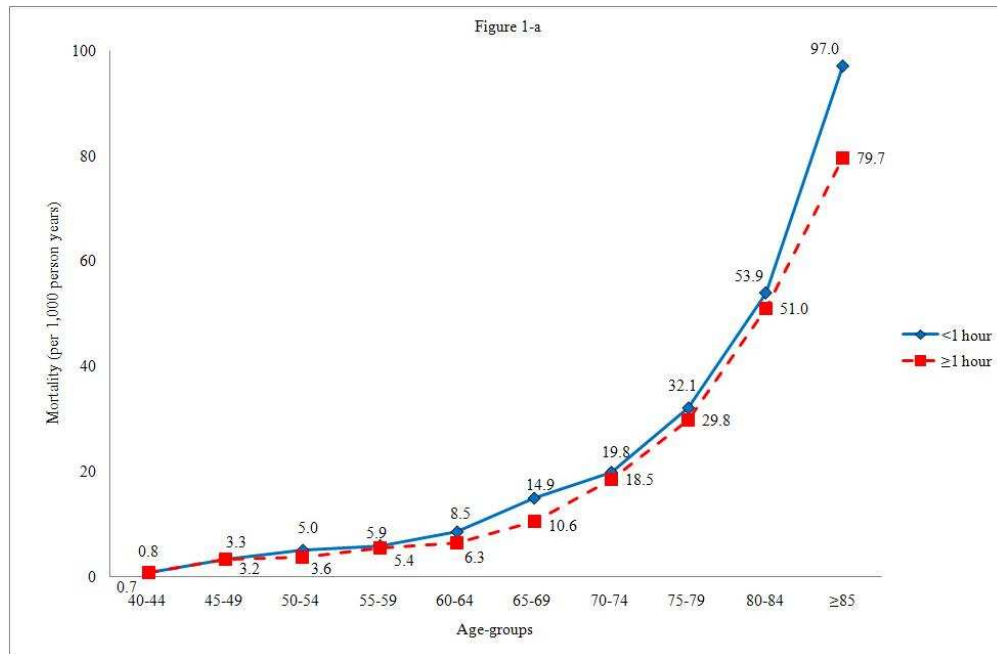
|       | Time spent walking | Univariate      |                         |                | Multiadjusted <sup>†</sup> |                         |                |
|-------|--------------------|-----------------|-------------------------|----------------|----------------------------|-------------------------|----------------|
|       |                    | Mortality ratio | 95% confidence interval | <i>p</i> value | Mortality ratio            | 95% confidence interval | <i>p</i> value |
| Men   | <1 hour            | 1.00            |                         |                | 1.00                       |                         |                |
|       | ≥1 hour            | 0.87            | 0.80 - 0.94             | 0.0009         | 0.90                       | 0.82 - 0.98             | 0.0153         |
| Women | <1 hour            | 1.00            |                         |                | 1.00                       |                         |                |
|       | ≥1 hour            | 0.89            | 0.77 - 1.03             | 0.1135         | 0.95                       | 0.82 - 1.10             | 0.4693         |

<sup>†</sup> Adjusted for age groups, smoking status, alcohol drinking, body mass index, self-rated health, sports and physical activity, and history of hypertension disease, diabetes mellitus, cancer, liver disease and kidney disease.

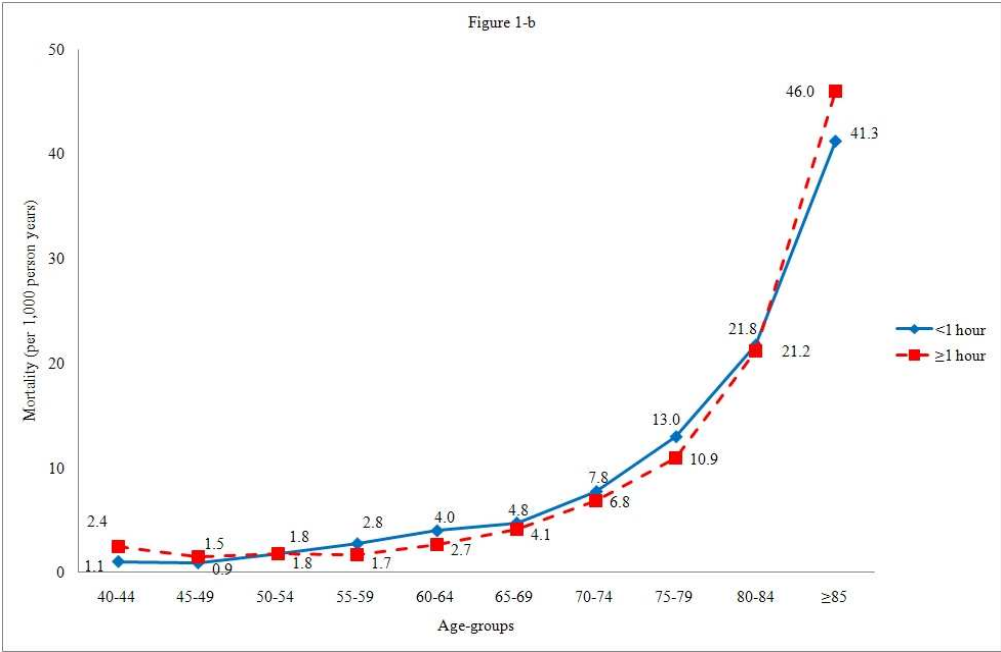
Table 3. Life expectancy and lifetime medical expenditure at age 40 years for time spent walking categories in 27,738 participants.

|       | Time spent walking                               | Univariate |                         |                | Multiadjusted <sup>†</sup> |                         |                |
|-------|--|------------|-------------------------|----------------|----------------------------|-------------------------|----------------|
|       |  | Estimate   | 95% confidence interval | <i>p</i> value | Estimate                   | 95% confidence interval | <i>p</i> value |
| Men   | Life expectancy at age 40 years (years)          |            |                         |                |                            |                         |                |
|       | <1 hour  | 42.41      | 41.45 - 43.26           |                | 43.43                      | 42.39 - 44.41           |                |
|       | ≥1 hour  | 44.19      | 43.15 - 45.19           | 0.0004         | 44.81                      | 43.66 - 45.94           | 0.0073         |
|       | Lifetime medical expenditure at age 40 years (£) |            |                         |                |                            |                         |                |
|       | <1 hour  | 107,023.2  | 101,093.6 - 113,066.3   |                | 107,544.2                  | 101,234.0 - 114,044.6   |                |
|       | ≥1 hour  | 94,402.1   | 87,812.3 - 101,248.0    | <0.0001        | 99,423.6                   | 92,515.9 - 106,694.7    | 0.0048         |
| Women | Life expectancy at age 40 years (years)          |            |                         |                |                            |                         |                |
|       | <1 hour  | 52.25      | 49.79 - 54.92           |                | 56.62                      | 53.17 - 60.62           | 0.2351         |
|       | ≥1 hour  | 54.25      | 51.38 - 57.48           | 0.0569         | 57.78                      | 54.02 - 62.22           |                |
|       | Lifetime medical expenditure at age 40 years (£) |            |                         |                |                            |                         |                |
|       | <1 hour  | 123,553.0  | 111,619.5 - 137,549.6   |                | 131,766.8                  | 115,902.4 - 150,714.3   |                |
|       | ≥1 hour  | 115,896.0  | 102,406.6 - 131,792.1   | 0.0644         | 128,161.2                  | 111,335.0 - 148,494.7   | 0.2559         |

<sup>†</sup> Adjusted for age groups, smoking status, alcohol drinking, body mass index, self-rated health, sports and physical activity, and history of hypertension disease, diabetes mellitus, cancer, liver disease and kidney disease.



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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

| Section/Topic             | Item # | Recommendation   | Reported on page # |
|---------------------------|--------|--|--------------------|
| Title and abstract        | 1      | (a) Indicate the study’s design with a commonly used term in the title or the abstract   | p. 1, 3            |
|                           |        | (b) Provide in the abstract an informative and balanced summary of what was done and what was found  | p. 3, 4            |
| Introduction              |        |  |                    |
| Background/rationale      | 2      | Explain the scientific background and rationale for the investigation being reported   | p. 5               |
| Objectives                | 3      | State specific objectives, including any prespecified hypotheses   | p. 5, 6            |
| Methods                   |        |  |                    |
| Study design              | 4      | Present key elements of study design early in the paper  | p. 6               |
| Setting                   | 5      | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection  | p. 7-9             |
| Participants              | 6      | (a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up   | p. 7-8             |
|                           |        | (b) For matched studies, give matching criteria and number of exposed and unexposed  |                    |
| Variables                 | 7      | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable   | p. 8-11            |
| Data sources/ measurement | 8*     | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | p. 8-11            |
| Bias                      | 9      | Describe any efforts to address potential sources of bias  | p. 10              |
| Study size                | 10     | Explain how the study size was arrived at  | p. 8               |
| Quantitative variables    | 11     | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why   | p. 10              |
| Statistical methods       | 12     | (a) Describe all statistical methods, including those used to control for confounding  | p. 9-11            |
|                           |        | (b) Describe any methods used to examine subgroups and interactions  | -                  |
|                           |        | (c) Explain how missing data were addressed  | -                  |
|                           |        | (d) If applicable, explain how loss to follow-up was addressed   | p. 8, 9            |
|                           |        | (e) Describe any sensitivity analyses  | p. 9-11-           |
| Results                   |        |  |                    |

|                   |     |  |           |
|-------------------|-----|--|-----------|
| Participants      | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed            | p. 7, 8   |
|                   |     | (b) Give reasons for non-participation at each stage   | p. 7, 8   |
|                   |     | (c) Consider use of a flow diagram   | -         |
| Descriptive data  | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders   | p. 12     |
|                   |     | (b) Indicate number of participants with missing data for each variable of interest  | -         |
|                   |     | (c) Summarise follow-up time (eg, average and total amount)  | p. 12     |
| Outcome data      | 15* | Report numbers of outcome events or summary measures over time   | -         |
| Main results      | 16  | (a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | p. 13, 14 |
|                   |     | (b) Report category boundaries when continuous variables were categorized  | p. 8, 10  |
|                   |     | (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period   | -         |
| Other analyses    | 17  | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses   | -         |
| Discussion        |     |  |           |
| Key results       | 18  | Summarise key results with reference to study objectives   | p. 15     |
| Limitations       |     |  |           |
| Interpretation    | 20  | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence                                   | p. 15-18  |
| Generalisability  | 21  | Discuss the generalisability (external validity) of the study results  | p. 17     |
| Other information |     |  |           |
| Funding           | 22  | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based  | p. 20     |

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).