

Original Article

Cohort study examining the association between vegetable consumption and weight gain in a single year among Japanese employees at a manufacturing company

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Background and Objectives: Overweight and obesity increase the risk of hypertension, type 2 diabetes, and other metabolic disorders and are increasing in Japan, particularly among men. Several prospective studies have suggested that high vegetable intake is inversely associated with weight gain. Here, the association between vegetable consumption and weight gain in a group of food manufacturing workers over the course of one year was investigated. **Methods and Study Design:** The study was a one-year cohort study of the nutrition and lifestyle survey. The study population consisted of 900 and 910 Japanese employees (aged 19-60 years) from a manufacturing company located in Musashino City, Tokyo, Japan, that were administered the same validated brief self-administered diet history and dietary lifestyle questionnaire in 2006 and 2007, respectively. Clinical examinations of body weight were also performed to assess changes in weight. We analyzed participants who responded in both 2006 and 2007 (n=478). **Results:** Risk of weight gain of more than 3 kg was significantly lower in the group consuming the most vegetables than in the group consuming the least, and this difference remained significant after adjustment for baseline age, sex, and consumption of other foods (*p* for trend=0.028). **Conclusions:** Weight gain was inversely associated with high consumption of vegetables. Encouraging Japanese employees to consume more vegetables may be an important strategy in controlling weight gain and preventing metabolic syndrome.

Key Words: vegetable consumption, weight gain, Japanese employees, one-year cohort study

INTRODUCTION

The Japanese National Health and Nutrition Examination Survey reported that 31.7% of Japanese adults (20-69 years old) for men were overweight or obese.¹ Overweight and obesity increase the risk of hypertension, type 2 diabetes, and other metabolic disorders.

Many health insurance associations and clinics have recently implemented health guidance issued by Japan's Ministry of Health, Labor, and Welfare for subjects over the age of 40 with metabolic syndrome, including specific weight loss goals at yearly checkups.² One prominent risk factor for metabolic syndrome is a weight gain of more than 3 kg in a single year. Japanese physicians include this item in medical interviews conducted at all health centers, as recommended in "Health guidance and checkups";³ a national campaign promoted by health care insurers.

With regard to possible causation, several prospective studies have suggested that high vegetable intake is inversely associated with weight gain.⁴⁻⁸ Examples include an association between vegetable intake and weight gain over 12 years among middle-aged women⁴ and over 4

years among women and men in the US,⁵ and an association between high vegetable intake and a suppression of a weight gain of more than 3.14 kg over 10 years in Spanish adults.⁶ To date, however, no evidence has been published on the association between vegetable consumption and weight gain in Japanese workers.

Moreover, most evidence to date has been obtained using a follow-up of more than one year.⁴⁻⁹ Assessment of weight gain over short periods is important in Japan, however, because questionnaires used in health checkups nationwide to collect information on the prevention of metabolic syndrome assess "the presence or absence of a weight gain of 3 kg or more in one year". To our knowl-

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Manuscript received 10 August 2014. Initial review completed 11 September 2014. Revision accepted 11 December 2014.

doi: 10.6133/apjcn.2015.24.4.08

edge, the question of whether or not low vegetable intake is a risk factor for a weight gain of 3 kg or more in one year has not been investigated. Further, most studies have been conducted in Western countries, and few studies have addressed the association between vegetable intake and weight gain in Asian populations.

Vegetable intake in Japan has declined in recent years in all generations, from teens to the elderly, and unlike other countries, the decline in Japan has been particularly pronounced in men.¹ Increasing obesity rates have also been greatest among men. That is, vegetable consumption has decreased as obesity rates have increased in Japan.¹ To support the efforts of obesity prevention workers, evidence on the association between diet or dietary behaviours and obesity is urgently required.

Here, to determine whether or not vegetable consumption among Japanese workers is associated with a weight gain of more than 3 kg in a single year, we examined the association between vegetable intake and weight gain in a population of Japanese workers using brief diet and lifestyle questionnaires and data from a yearly health examination.

MATERIALS AND METHODS

Study population

This study was one-year cohort study of male and female Japanese employees aged 19-60 years at study initiation at a 2006 health check. The target company was a food manufacturing company in Musashino City, Tokyo, with 1,250 employees. Of these workers, 900 participants were recruited in May 2006 and 910 participants in May 2007. We limited our analysis to participants who had received annual health checkups and completed questionnaires in both years. Information for the study was sent by interoffice mail before the annual health check in both years, and consent forms were collected from the participants with the self-administered questionnaires. These questionnaires were collected at each annual health checkup (n=801 in 2006 and n=810 in 2007). Responses were received from 89% of participants in 2006 and 88% in 2007. Three investigators independently checked each survey for missing data and solicited information to complete the questionnaires. For the present analyses, we included those participants who responded in both 2006 and 2007 (n=478). This study was conducted in accordance with the guidelines of the Declaration of Helsinki, and all procedures involving human subjects/patients were approved by the Human Research Ethical Committee of the University of Kagawa (approval no. 257). Written informed consent was obtained from all subjects/patients.

Questionnaires

We distributed a self-administered life-style questionnaire and a brief-type self-administered diet history questionnaire (BDHQ). The lifestyle questionnaire collected information on demographic factors, including sex, age, marital status, job type, attitudes and behaviours regarding food and quality of life, as well as knowledge of food preparation and nutritional requirements. Job type was characterized as management, supervisor, or regular employee.

The BDHQ was derived from the previously validated

self-administered diet history questionnaire (DHQ).^{10,11} Energy-adjusted food consumption used in the present study, presented as grams of foods consumed per 4,184 kJ (1,000 kilocalories), was validated against a 16-day weighed dietary record as a gold standard in a previous report.¹¹ Differences in mean intakes were minimal, and correlation coefficients between the two methods were acceptable. Vegetable intake was assessed by asking respondents to note the frequency with which they consumed green and yellow vegetables, other vegetables, pickled vegetables, mushrooms, and seaweed. Responses were validated against the gold standard and found to have a Spearman coefficient of correlation of 0.62 for men and women, signifying moderate correlation.

Health check-up data

Body weight was measured in kilograms using electronic weight scales with direct digital reading. Height was measured in centimetres with the person standing without shoes. Body mass index (BMI; weight [kg]/height [m]²) was calculated from weight and height measurements. All participants were measured at the same clinic using the same measurement equipment.

Statistical analysis

Questionnaires with incomplete or implausible information (total daily energy intake <1/3 of the energy requirement for each age and sex class, assuming a low level of physical activity or >2/3 of the energy requirement for each age and sex class, assuming a high level of physical activity; n=41) were excluded based on the exclusion criteria of the preceding study.¹² After exclusion, a total of 437 respondents who provided information in both 2006 and 2007 remained in the analysis. We conducted a cross-sectional analysis of the associations between baseline covariates and the intake of vegetables. Vegetable intake was categorized into quartiles, and mean food consumption was calculated (g/4,184 kJ [1,000 kcal]). Other categories were expressed as percentages. Participants were divided into quartiles based on their vegetable consumption adjusted for energy using the density method, where energy-adjusted values were calculated using the amount of each food group consumed daily per 4,184 kJ (1,000 kcal) of daily energy intake. We performed binomial logistic multiple regression analysis to examine the association between vegetable consumption and the risk for weight gain of 3 kg or more in one year, adjusting for sex, age, weight, marital status, and intake of food with the potential to cause weight gain. Statistical tests were conducted using calorie-adjusted values. All statistical analyses were performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). *P*-values were two-tailed, and *p*<0.05 was considered significant.

RESULTS

The characteristics of participants, stratified by quartile of vegetable consumption, are shown in Table 1. Mean energy-adjusted consumption of vegetables ranged from 57.2 g/4,184 kJ (1,000 kcal) in the lowest quartile to more than 143.7 g/4,184 kJ (1,000 kcal) in the highest quartile at baseline. Participants in the highest quartile of vegetable consumption were significantly older, more likely to

be women, and were more often married. Baseline and one-year body weight decreased in parallel with vegetable consumption. Weight change over a single year in participants in the highest quartile of vegetable intake was 0.6 kg less than that in participants in the lowest quartile (p for trend=0.029). BMI measured at both baseline and after one year did not differ by quartile (p for trend=0.089). The participants with a higher consumption of vegetables also consumed the greatest amounts of fish, milk and milk products, dressing, and Japanese sweets, but consumed less cereals, sweet beverages, sugar, and alcohol than participants in the lowest quartile (Table 2).

Higher vegetable consumption was associated with a reduced risk of rapid weight gain (Table 3). Compared with participants in the lowest quartile, crude odds of weight gain ≥ 3 kg in a single year for participants in the second, third, and fourth quartiles were 0.73, 0.46, and 0.35, respectively (Model 1; p for trend=0.016) after adjustment for sex, age, marriage status, baseline weight,

and consumption of fish, cereals, fruits, milk, Japanese sweets, sweetened beverages, sugar, dressing, and alcohol (Model 4; p for trend=0.028). Compared to participants in the lowest quartile of vegetable consumption (<57.2 g/4,184 kJ [1,000 kcal], participants in the highest quartile (≥ 143.7 g/4,184 kJ [1,000 kcal]) had a 73% lower risk of gaining ≥ 3 kg weight in a single year (adjusted OR 0.27, 95% CI, 0.08-0.99). However, participants in the second quartile (57.2 - 93.6 g/4,184 kJ [1,000 kcal]) and third quartile (93.6 - 143.7 g/4,184 kJ [1,000 kcal]) did not have a significantly lower risk of rapid weight gain, with risk reductions of 31% (OR=0.69, 95% CI, 0.29-1.68) and 63% (OR=0.37, 95% CI, 0.13-1.07), respectively.

DISCUSSION

In this study, we confirmed that vegetable intake was inversely associated with the risk of a body weight increase of 3 kg or more over one year in Japanese employees. This association was not modified by adjustment for

Table 1. Characteristics of the study population (n=437) by quartiles of vegetable intake at baseline

Characteristic	Q ₁ (n=110)	Q ₂ (n=108)	Q ₃ (n=109)	Q ₄ (n=109)	p value [†]	p for trend [‡]
Mean (SD)						
Age (y)	31.0 (9.7)	33.6 (10.3)	39.0 (11.3)	44.3 (12.7)	<0.001	<0.001
Weight (kg)	63.0 (10.8)	62.5 (11.1)	60.4 (10.3)	57.6 (10.9)	0.001	<0.001
1-year weight gain (kg)	0.6 (2.3)	0.4 (2.5)	0.1 (2.2)	0.0 (2.2)	0.171	0.029
BMI (kg/m ²)	22.1 (3.4)	22.0 (3.6)	22.2 (3.2)	22.0 (3.5)	0.943	0.893
BMI after 1 year (kg/m ²)	22.4 (3.4)	22.2 (3.6)	22.4 (3.3)	22.2 (3.5)	0.968	0.816
SBP (mmHg)	124 (13.3)	121 (12.4)	124 (13.5)	121 (13.0)	0.148	0.465
DBP (mmHg)	70.2 (11.3)	69.5 (11.6)	71.4 (11.5)	70.8 (10.5)	0.617	0.420
Proportion (%)						
Weight gain ≥ 3 kg	14.5	11.1	7.3	5.6	0.107	0.015
Male	85.5	78.7	66.4	39.4	<0.001	<0.001
Unmarried	72.7	63.0	50.0	47.2	<0.001	<0.001
Regular employee [§]	94.5	95.4	96.4	97.2	0.961	0.080

Q₁: <57.2 g/4,184 kJ [1,000 kcal]; Q₂: 57.2 - 93.6 g/4,184 kJ [1,000 kcal]; Q₃: 93.6 - 143.7 g/4,184 kJ [1,000 kcal]; Q₄: ≥ 143.7 g/4,184 kJ [1,000 kcal].

DBP: diastolic blood pressure; SBP: systolic blood pressure.

[†]Quantity data: one-way analysis of variance; Categorical data: χ^2 test

[‡]Quantity data: trend test of general linear; Categorical data: χ^2 test

[§]Regular employee: indicates an employee in a non-managerial position

Table 2. Nutrients and foods of participants (n=437) by quartiles of vegetables intake at baseline

Nutrient/food type	Q ₁ (n=110)	Q ₂ (n=108)	Q ₃ (n=110)	Q ₄ (n=109)	p value [‡]	p for trend [§]
Energy (kcal)	1884 (557)	1969 (613)	1971 (574)	1878 (536)	0.444	0.952
Food type (g/4184 kJ [1000 kcal])						
Vegetables	33.4 (15.9)	74.7 (9.8)	112 (14.0)	215 (55.1)	<0.001	<0.001
Cereals	247 (83.4)	248 (64.3)	218 (63.4)	183 (67.1)	<0.001	<0.001
Meat	39.1 (25.4)	35.9 (17.0)	39.5 (17.4)	35.9 (20.4)	0.366	0.489
Fish	25.8 (27.0)	29.9 (17.6)	36.9 (18.7)	45.2 (24.2)	<0.001	<0.001
Milk/dairy products	48.4 (55.3)	46.0 (46.1)	55.1 (55.6)	71.7 (58.5)	0.002	0.001
Fruits	12.3 (12.8)	13.5 (12.6)	20.8 (18.8)	32.1 (27.6)	<0.001	<0.001
Western sweets	25.2 (25.9)	26.0 (19.7)	22.8 (20.1)	15.1 (15.9)	0.520	0.157
Japanese sweets	2.5 (4.1)	3.0 (3.7)	3.6 (4.3)	3.5 (4.8)	0.194	<0.001
Sweetened beverages [†]	125 (136)	77.8 (87.4)	49.3 (56.5)	30.4 (50.4)	<0.001	0.045
Sugar	2.9 (3.7)	2.7 (3.1)	2.5 (3.1)	1.8 (2.6)	0.053	0.009
Dressing	2.3 (2.7)	3.1 (2.2)	4.1 (2.4)	4.2 (3.6)	<0.001	<0.001
Alcohol	7.0 (10.4)	5.8 (8.0)	5.0 (7.0)	3.2 (6.5)	0.005	<0.001

Q₁: <57.2 g/4,184 kJ [1,000 kcal]; Q₂: 57.2 - 93.6 g/4,184 kJ [1,000 kcal]; Q₃: 93.6 - 143.7 g/4,184 kJ [1,000 kcal]; Q₄: ≥ 143.7 g/4,184 kJ [1,000 kcal].

[†]Sweetened beverages: include carbonated soda or coffee, such as cola, soft drink, canned coffee etc.

[‡]Quantity data: one-way analysis of variance.

[§]Quantity data: trend test of general linear.

Table 3. Odds ratios (95% CI) for weight gain (≥ 3 kg in 1 year) according to energy-adjusted quartiles of vegetable consumption

	Q ₁ (n=110)	Q ₂ (n=108)	Q ₃ (n=110)	Q ₄ (n=109)	<i>p</i> for trend ^{††}
Weight gain of ≥ 3 kg (n)	16	12	8	6	
Model 1 [†]	1 (ref.)	0.73 (0.33, 1.64)	0.46 (0.19, 1.13)	0.35 (0.13, 0.92)	0.016
Model 2 [‡]	1 (ref.)	0.73 (0.33, 1.63)	0.45 (0.18, 1.11)	0.33 (0.12, 0.93)	0.018
Model 3 [§]	1 (ref.)	0.72 (0.32, 1.62)	0.44 (0.19, 1.13)	0.34 (0.12, 1.01)	0.036
Model 4 [¶]	1 (ref.)	0.69 (0.29, 1.68)	0.37 (0.13, 1.07)	0.27 (0.08, 0.99)	0.028

Q₁: <57.2 g/4,184 kJ [1,000 kcal]; Q₂: 57.2 - 93.6 g/4,184 kJ [1,000 kcal]; Q₃: 93.6 - 143.7 g/4,184 kJ [1,000 kcal]; Q₄: ≥ 143.7 g/4,184 kJ [1,000 kcal].

CI: confidence interval; ref.: reference.

[†]Model 1: unadjusted

[‡]Model 2: gender adjusted

[§]Model 3: Model 2 + age adjusted

[¶]Model 4: Model 3 + all confounding factors (marriage status, weight at baseline, and energy-adjusted consumption of fish, cereals, fruits, milk, Japanese sweets, sweetened beverages, sugar, dressing, and alcohol)

^{††}*p* for trend: the median intake values in each quartile were assigned and treated as a continuous variable.

baseline body weight and intake of foods other than vegetables. Our findings of an association between the risk of body weight increase and vegetable intake support the belief that high vegetable intake reduces the risk of obesity.

Vioque et al⁶ reported an association between vegetable intake and weight gain over a period of 10 years. They found that as vegetable intake increased, the risk of gaining more than 3.41 kg over 10 years was reduced, with an odds ratio of a weight gain of more than 3.41 kg over 10 years between the group consuming the most vegetables and the group consuming the least of 0.18 (95% CI 0.05 to 0.73). In a long-term cohort study that followed middle-age women for 12 years, He et al⁴ reported that the risk of a weight gain of 25 kg or more in the group consuming the most vegetables was 0.76 times that in the group consuming the least vegetables. Although these studies report a long-term and gradual association between a reduced risk of weight gain and high vegetable intake, the present study focused on weight gain in the much shorter period of one year.

Although the mechanism by which vegetable consumption might prevent weight gain has not been clarified, because fruits and vegetables are rich in vitamins, minerals, and dietary fibre, they have attracted considerable attention in recent years, and many studies have assessed the relation between combinations of fruits and vegetables and weight gain.^{8,13,14} However, fruits are mostly consumed raw and without the use of oil, and this type of consumption seems very different from that of vegetables, which are often fried or otherwise cooked and dressed with sauce.¹⁵ In addition, while vegetables are generally a side dish of the meal, fruits are often eaten as snacks, but not as substitutes for meals, and although fruits and vegetables might belong to the same group at the nutrient level, they should be classified as separate groups from the perspective of meals and eating habits.¹⁵ In previous studies, in cases where only vegetables or only fruits were investigated, or fruits and vegetables were distinguished as separate groups, results were not always the same as when fruits and vegetables were considered as a single food group.^{4,5} Therefore, we focused only on vegetable intake in the present study.

In previous studies that showed an association between

vegetable intake and weight gain in long-term follow-up,^{4,6-8} significant decreases in the risk of body weight gain were observed in the group consuming the most vegetables (approximately 140 g/1000 kcal) in comparison with the group consuming the least vegetables, but no significantly reduced risk was observed in comparison with the other groups. In the present study, results after multivariate data adjustment showed no association of risk ratios in the second- or third-quartile intake groups in comparison with the first-quartile intake group. That is, the risk of body weight increase in the groups consuming 93.6 to 143.7 g of vegetables per 4,184 kJ (1,000 kcal) was not reduced compared with the group consuming the least amount of vegetables. Vergnaud et al¹⁵ found no correlation between a vegetable intake of 100 g and body weight gain in persons other than those who had quit smoking.

In our study, no significant effect was observed in the second- or third-quartile intake groups. This finding suggests that the protective effect of high vegetable intake on short-term body weight gain may require an intake of more than 143.7/4,184 kJ (1,000 kcal). However, we cannot deny the possibility that the population sample size was too small to detect significant differences between the intake groups. Many recent intervention studies have assessed the benefit of high vegetable intake; however, most studies investigated vegetable intake of less than one serving.¹⁶⁻¹⁸ To be effective, obesity prevention programs must be based on components which reliable evidence has suggested as beneficial. Our study suggests that persons with relatively low vegetable intake (<57.2 g/4,184 kJ [1,000 kcal]) should be targeted and that daily vegetable intake should be increased to 143.7 g/4,184 kJ (1,000 kcal) or more.

Limitations and strengths

Our study has several limitations that warrant mention. Previous studies of the association between vegetable intake and long-term weight gain adjusted for exercise and smoking in their analyses. For participants who stopped smoking, vegetable intake was greater and the risk of weight gain was lower.¹³ However, we did not collect exercise or smoking data and were therefore unable to adjust for these factors. Second, as the population

of our study was recruited from a single factory in Tokyo, caution should be taken in generalizing our results. In addition, because the number of subjects was insufficient to perform stratified analysis based on sex, we performed multiple regression analysis using sex as a confounding factor. Finally, use of a self-reported questionnaire instead of direct assessment of consumed food carries the risk of introducing response biases, including social desirability and recall biases.

The main strength of this study was that all participants were Asian people (Japanese). In addition, we consider that the use of validated self-report questionnaires was acceptable for the purposes of our study. Additionally, weight measurements, which were thought to be most susceptible to self-report bias, were taken at the health checkups by medical staff using the same scales for both checkups. Further, nutrition data were considered to be of high quality because data were collected and checked in triplicate by trained dietitians, and there were no missing data. Response rates were also good, with more than 80% of participants responding to the questionnaires.

Allowing for the limitations above, the present study provides important data regarding the association between vegetable intake and a weight gain of 3 or more kg in a single year. As the tested association corresponds to the question used by physicians to assess the risk of metabolic syndrome in health checks throughout Japan, our research is more directly applicable to the development of programs to prevent metabolic syndrome in Japan than previous research on the association between vegetable intake and long-term weight gain. However, future longitudinal studies examining the potential association between increasing vegetable consumption and weight gain are needed to confirm these findings.

ACKNOWLEDGEMENTS

This study was partially funded by the Japan Society for the Promotion of Science (JSPS) Kakenhi (Grants-in-Aid for Scientific Research) (No. 15K00882) for fiscal years 2015 to 2017. This study was conducted as a part of the scientific research program of the Japanese Ministry of Health, Labour, and Welfare by the research leader (Dr Ishida) in the fiscal years 2006-2008.

AUTHOR DISCLOSURES

None of the authors have any conflicts of interest to declare.

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Original Article

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队列研究：监测一家日本制造公司的员工中蔬菜摄入量 and 一年内增重的关系

背景与目的：超重和肥胖会增加高血压、2型糖尿病和其他代谢性疾病的风险，这种现象在日本呈现增加趋势，特别是男性。一些前瞻性研究表明，高的蔬菜摄入量与增重呈负相关。该研究对一家日本制造公司的员工蔬菜摄入量 and 增重之间的关系进行了为期一年的研究。**方法与研究设计：**该研究是一个为期一年的营养和生活方式的调查研究。在2006和2007年，对日本东京武藏野市一家制造公司的900和910名日本员工（年龄在19~60岁）分别对其进行简易饮食史和饮食生活方式的问卷调查，同时也进行体重的临床检查以便评估体重的变化。我们分析了在2006和2007均参与调查的478名对象。**结果：**摄入蔬菜最多的人群中，增重超过3千克的风险显著低于摄入蔬菜最少者；在调整基线年龄、性别和其他食品消费量的影响后，这种差异仍然存在（趋势 $p=0.028$ ）。**结论：**增重与高的蔬菜摄入量呈负相关。鼓励日本员工多吃蔬菜，可能是控制增重和预防代谢综合征的重要策略。

关键词：蔬菜消费量、增重、日本员工、一年的队列研究