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I. Abstract

The expanding disparity in health is a serious global problem related to human rights. The World health organization (WHO) aims to alleviate the influence of differences in socioeconomic status on health disparity through interventions for dietary behavior and the food environment. In our multipurpose cross-sectional survey, about 90% of respondents did not meet the recommended daily intake of vegetables (350 g per day, 5 dishes in small bowls), and this ratio was higher for those with a lower income. Appropriate vegetable intake has a preventive effect on various lifestyle diseases. As far as I know, no practical intervention study focuses on the disparity in adult vegetable intake. To reduce the risk of disease, it is necessary to develop a nutrition education program tailored to the needs of participants. This study aimed to develop a health promotion strategy to reduce the disparity in vegetable intake. Furthermore, the research comprised three studies.

A Japanese online research service company with data on approximately 111,000 people (in September 2015) was registered. The research company randomly selected 8,284 participants (Study 1) and 8,564 participants for Studies 2 and 3. The participants were adults aged from 30 to 59 years, and matched the distributions of sex and age in Japan.

To develop an effective education program, it is important to plan using appropriate behavioral science theory. The aim is to structure several theories and elements to predict a change in vegetable intake and to examine those useful for the program according to income. The observation variable was vegetable intake, and the latent variables were stage of change, attitudes, subjective norms, and perceived behavioral control (PBC). I performed multiple group structural equation modeling to identify the predictors of vegetable intake as a behavior. The fit indices for the tested model were acceptable (normed fit index: NFI = 0.95, comparative fit index: CFI = 0.96, root mean square error approximation: RMSEA = 0.038). In addition, high levels of consistency were observed when the four items of the observation variable ('meal consisting of grain dishes, fish and meat dishes, and vegetable dishes,' 'vegetable dishes (dishes made mainly from vegetables)' 'green/yellow vegetables,' and 'fruits') were analyzed in the model for all household incomes. Furthermore, high levels of internal consistency were observed for these items. For those with an income of less than 3,000,000 JPY, PBC directly affected vegetable intake behavior. The results suggest that a nutrition education intervention to encourage a stage of change by reinforcing PBC and the Japanese dietary pattern may promote desirable levels of vegetable intake.

For effective nutrition education, the target person's perception of the neighborhood food environment is important, as is improving the physical food environment by supporters. The objective is to examine the perception of the neighborhood food environment related to desirable vegetable intake according to income. As such, associations were assessed using binomial logistic regression analyses, with vegetable intake as the dependent variable and perceptions of the neighborhood food environment as the independent variable. One is the perception of a reasonable price for balanced foods, and another the perception of the "social capital of food" defined by culture and tradition, such as a good atmosphere in the neighborhood. In addition, a focus on social capital may not only promote vegetable intake behavior, but also the health of the community as a whole. It is important for the target person to focus on a food environment that promotes desirable vegetable intake behavior.

To verify whether the dietary education program developed based on these intervention plans can reduce the disparity in vegetable intake due to differences in income, practical intervention research is needed. The objective is to create an intervention protocol that conforms to international standards for a nutrition education program aimed at increasing vegetable intake. The guidelines for preparing protocols for clinical trials, namely the "SPIRIT 2013 Statement," were followed. The study design is a randomized controlled trial (RCT). Participants were assessed through a self-report completed at three time points: baseline (T1), post intervention (T2), and a follow-up three months later (T3). The web intervention period was five weeks long. The program comprised 20 pages divided into 5 steps (each step consists of 4 pages), and each step was updated every week (e.g., Pre-contemplation → Contemplation). The program was based on the transtheoretical model (TTM), and employed the behavioral modification techniques of skill, attitude, PBC (Study 1-1), and perceptions of the neighborhood food environment (Study 1-2). As a research design, web-based nutrition education can secure a large sample and determine the effects according to income. Developing protocols that satisfy international standards in practice intervention studies means that this research will be an international achievement contributing to solving the disparity in dietary intake.

Constructing a scientific basis for nutrition education in practice is urgent. The objective is to verify the reduction in the disparity in vegetable intake due to differences in household income using a web-based nutrition education program. The authors compared groups and times to determine the intervention effect on vegetable intake using two-way analyses of variance (ANOVA). For the intervention group in the low-income category at T1,

vegetable intake was lower than that of the intervention and control groups in the middle-income category. Vegetable intake of the control group in the low-income category at T1 was lower than that of the vegetable intake for both the intervention and control groups in the middle-income category. There was no difference between the intervention and control groups for both income groups. From T1 to T2, the vegetable intake of the intervention group in the low-income category increased (0.42 servings (SV); 95% confidence interval (CI): 0.11–0.72). At T2 and T3, the difference between the low-income and middle-income categories had disappeared. A nutrition education program focusing on improving PBC based on the stage of change may fill the gap between low- and middle-income vegetable intake according to the needs of participants.

Through our practical research, I succeeded in reducing the disparity in vegetable intake due to differences in income for the first time. This achievement has become one health promotion strategy for those disadvantaged in terms of socioeconomic status, a problem that until now has not been solved, contributing greatly to this field. As such, the study helps to build evidence to solve the disparity in dietary intake. In the future, I plan to develop a nutrition education program for the public. It is expected that it can be applied as non-face-to-face nutrition education using a large population web-based nutrition education program, or as a classroom program in local governments and companies.

Ⅱ. General Introduction

The global spread of health inequality is a serious human rights problem. Low socioeconomic status (SES) from low income and education has been found to be associated with high mortality and morbidity [1, 2]. Low SES also affects the quality of food intake [3], and is related to many other dietary problems. The need for improving dietary habits has therefore been pointed out in several studies [4-8]. In order to solve this global social problem, WHO aims to reduce health disparity caused by differences in socioeconomic status through interventions in the eating behaviors and food environments of low-SES populations [9].

Japan, for example, has one of the highest levels of longevity in the world, with a lower risk of cardiovascular disease and obesity than Europe and the United States [10]. This exemplifies why health disparities have recently been recognized as a worldwide social problem [11-13]. Although social security has improved, health promotion strategies such as nutrition education are still underdeveloped, and practical strategies for reducing dietary disparities are lacking; therefore, a solution is urgently required.

For example, appropriate vegetable intake prevents cancer [14, 15] and obesity [16], and reduces the risk of cardiovascular disease [17, 18] and other lifestyle-related diseases [19]. Health Japan 21 (the second term) [20] recommends a vegetable intake of 350g (five servings) per day for adults to prevent lifestyle-related diseases. Nevertheless, approximately two-thirds of Japanese adults do not meet this recommendation, and low-income households consume few vegetables [21] (per day among those in the lowest income: men 254g, women 282g). The author investigated a multipurpose cross-sectional survey on socioeconomic status and diet in Japan. I found that the lower the people's income and education, the more unhealthy their food environments and the overall quality of their eating habits. The relationship between eating behavior and income, which nutrition education aims to improve, is larger than that between education and eating behavior; thus, promotion of vegetable intake is its top priority. Unfortunately, at present, there is no practical intervention study on reducing the disparity in vegetable intake among adults. In order to reduce disease risk early, health promotion strategies for raising the vegetable intake of low-income Japanese are urgently required.

To focus on income and develop a nutrition education program that is also beneficial for low-income people, it is necessary to verify the intervention effect for each income level. The author assumed that a nutrition education program based on subject assessments and tasks will increase vegetable intake. The purpose of this study is to develop a population strategy

aimed at reducing the disparity in vegetable intake. The research consists of the following three stages. Study 1 examines the differences in income related to individual and environmental factors and vegetable intake. Based on the results of Study 1, Study 2 develops a nutrition education program and intervention protocol for increasing vegetable intake. Study 3 implements and evaluates the intervention protocol developed in Study 2. As our hypothesis verifies, this research may contribute to solving the global problem of disparity in vegetable intake.

Ⅲ. Literature Review

1. Health and dietary disparity problem

1-1. Relationship between socioeconomic factors and health

Reducing health disparity is an urgent issue. A report on the Social Determinants of Health Discussion Paper 2 in 2010 [9] shows a conceptual framework for action. Socioeconomic and political context (governance, macroeconomic policies, social policy, public policies, culture, and societal values) determine the most important structural stratification, and their proxy indicators include income, education, occupation, social class, gender, and race/ethnicity. The contexts, structural mechanisms, and resultant socioeconomic position of individuals are “structural determinants,” and I refer to them as the “social determinants of health inequities.” The underlying social determinants of health inequities operate through a set of intermediary health determinants to shape health outcomes. The vocabulary of “structural determinants” and “intermediary determinants” underscores the causal priority of the structural factors. The main categories of the intermediary determinants of health are the following: material circumstances (e.g. the financial means to buy healthy food, warm clothing, etc.); psychosocial circumstances (psychosocial stressors, stressful living circumstances and relationships, and social support and coping style); behavioral circumstances (nutrition, physical activity, tobacco and alcohol consumption, which are distributed differently among different social groups), and/or biological factors (including genetic factors); and finally the health system itself. Suggestions for concrete solutions to end health disparity are needed not only in developing countries but also in developed ones, including Japan.

Kagamimori et al. [11] discussed the impact of individuals' SES on health in Japan with regard to educational status, income level, and unemployment. Their review is based on indexes between 1990 and 2007. Japan is still one of the healthiest nations in the world, and social inequalities within the population are less expressed than in less-developed ones. However, Kagamimori et al. [11] found that socioeconomic differences in mortality, morbidity, and risk factors are not uniformly small there. The majority of papers on the topic of Japanese health disparities investigate the relationship between education, occupational class, and health, but low income and unemployment have not been sufficiently examined. They nonetheless indicate that the magnitude of this social stratification will increase in the future.

Among SES factors such as educational status, income level, and unemployment, health disparity due to income disparity has received attention. In 2009, Kondo et al. [12] reported on the relationship between Japanese income disparity and health. Their meta-analysis included 59,509,857 subjects in nine cohort studies, and 1,280,211 participants in 19 cross-sectional studies. Their meta-regressions showed stronger associations between income inequality and health outcomes in studies with higher Gini coefficients (>or=0.3), which were conducted with data from after 1990.

Moreover, Kondo [13] used meta-analysis to investigate the health impact of socioeconomic disparities, as well as the pathways that underlie those disparities. He found that a large segment of the population suffers high mortality risks and low self-rated health that are attributable to income inequality. He analyzed Japanese national representative survey data and performed a large-scale cohort study of Japanese older adults (Aichi Gerontology Evaluation Study; AGES cohort), and concluded that income inequality might have adverse impacts on individual health. Therefore, further studies are needed to attain a better understanding of the social determinants of health in a rapidly changing society.

1-2. Food intake disparity due to differences in socioeconomic status

SES disparity also affects food intake. For example, Darmon [3] reviewed relations between SES and diet quality. He found that a large body of epidemiological data shows how diet quality follows a socioeconomic gradient. His review suggested that whole grains, lean meats, fish, low-fat dairy products, and fresh fruit and vegetables are more likely to be consumed by higher SES population groups. Thus, health promotion strategies based on recommending low-cost but high-nutrition foods to low-income people may be effective.

A large body of epidemiological data from Western countries also shows that higher-SES individuals consume higher-quality diets. However, evidence on such socioeconomic differences in the diets of Japanese is utterly lacking. In 2009, Murakami et al. [22] examined the association of SES and dietary intake in pregnant Japanese women (n=1, 002) for the first time. They cross-sectioned their SES by education, occupation, and household income. Dietary intake was estimated using a validated, self-administered, comprehensive diet history questionnaire. They found that higher education was associated with a higher intake of vegetables, fish and shellfish, and potatoes, but a lower intake of rice. As for occupation, housewives had a higher intake of dietary fiber, magnesium, iron, vitamin A, folate, and pulses

and nuts than did working women. Household income was not associated with any nutrient or food intake that he examined. Murakami concluded that education, but not occupation or household income, was positively associated with favorable dietary intake patterns in this group of pregnant Japanese women. Since these results are limited to pregnant women, accumulation of research results from other population segments is necessary for generalization.

However, National Health and Nutrition Survey [21] has reported that disparity in food intake is correlated with disparity in income in Japan. This research found that vegetable intake was different depending on income: among those in the lowest income (under 2,000,000 JPY): men 254g, women 282g per day; among those in the highest income (more than 6,000,000 JPY): men 322g, women 314g per day. I can therefore hypothesize that an approximately 70g (1 serving) increase in vegetable intake might help lower-income groups to catch up with higher ones, while partially resolving the vegetable intake deficiency among Japanese adults.

Finally, Nakamura et al. [23] examined the "relationship between SES (household income and education) and eating behavior" in 3,137 Japanese (1,580 men and 1,557 women) aged 30 to 59. Then a Japanese online research service conducted an Internet-based cross-sectional survey in February 2014 with data on approximately 160,300 adult registrants, including their socio-demographic attributes. A trend was calculated for three categories of household income (less than 3,000,000 JPY; 3,000,000 to 7,000,000 JPY; and over 7,000,000 JPY) and education (junior high/high school, two-year college, and four-year college/graduate school). The service found that higher household income and education were significantly associated with higher rates of eating vegetables, using the information on nutrition labels, and conversation with family or friends during meals. The most strongly associated factor was eating vegetables, and the magnitude of the disparity was more related to income than to education, unlike Murakami's finding.

1-3. Health effects of appropriate vegetable intake

Appropriate vegetable intake prevents obesity [16], and reduces the risk of cardiovascular disease (CVD) [17-19] and other lifestyle-related diseases [24]. The World Cancer Research Fund and the American Institute for Cancer Research (WCRF) [25] concluded that fruit and vegetables, as foods containing carotenoids, possibly decrease the risk

of lung and gastric cancer. However, low-SES individuals worldwide remain low in vegetable intake [21], promoting higher vegetable intake among them is important for reducing global health disparities.

In one study, Mozaffarian et al. [16] suggested that appropriate vegetable intake prevents long-term weight gain and obesity. They used a prospective study involving three cohorts of 120,877 U.S. men and women who were not suffering from chronic diseases or obesity at baseline. There were follow-up periods from 1986 to 2006, 1991 to 2003, and 1986 to 2006. Within four-year periods, participants gained an average of 1,519.5g. Also, after increased servings of individual dietary components, their four-year weight change was inversely associated with the intake of vegetables (-99.66g) and fruits (-221.97g).

There have also been some reports on the relationship between adequate fruit and vegetable intake and reduction of CVD risk. In one example, Gillman et al. [17] examined the effect of fruit and vegetable intake on the risk of stroke among male participants aged 45 through 65 years (n=832) who were free of CVD at baseline (from 1966 to 1969, this study design was the cohort in the Framingham Study, a population-based longitudinal study). They concluded that intake of fruit and vegetables may protect against strokes in men. Subjects' diets were assessed at baseline by means of a single 24-hour recall. At baseline, the mean number of fruit and vegetable servings per day was 5.1 (standard deviation (SD) 2.8). Age-adjusted relative risk (RR) for all strokes, including transient ischemic attack, was 0.78 (95% Cl: 0.62 - 0.98) for each increase of three servings per day. This was part of the "Framingham heart study" started in 1948. The cause of coronary artery disease was pursued using "epidemiology," which is a method of research in infectious diseases.

In another example, Bazzono et al. [18] reviewed the scientific evidence on then-current dietary recommendations to increase fruit and vegetable intake for CVD prevention. They reported that for the functional aspects of fruit and vegetables, available evidence indicated that people who consume more fruit and vegetables often have lower risk factors for CVD, including hypertension, obesity, and type 2 diabetes mellitus. These recent and large prospective studies also showed a direct inverse association between intake of fruit and vegetable and the development of CVD incidents, such as coronary heart disease and stroke.

Such results are similar to findings on Japanese people. For example, Nagura et al. [19] examined the association of plant-based food intake with CVD and total mortality. Their Collaborative Cohort Study for Evaluation of Cancer Risk surveyed 25,206 men and 34,279

women aged 40 to 79 years whose fruit, vegetable, and bean intakes were assessed by a questionnaire at baseline from 1988 to 1990. The findings suggested that intake of plant-based foods and fruit were associated with reduced mortality from CVD and all other causes among Japanese men and women. However, vegetable intake was inversely associated with total CVD (Hazard ratio (HR) = 0.88, 95%CI; 0.78-0.99). Continued accumulation of Japanese research data is needed because there has thus far been no definite conclusion.

Then Shimazu et al. [24] conducted a pooled analysis of data from four large-scale cohort studies carried out in Japan. In particular, they investigated the association of fruit and vegetable intake with gastric cancer risk using original data from four population-based prospective cohort studies encompassing 191,232 participants. As a result, they suggested that vegetable intake reduces gastric cancer risk, especially the risk of distal gastric cancer among men. Specifically, he reported that the multivariate-adjusted HR (95% CI: P for trend) for the highest versus the lowest quintile of total vegetable intake was 0.89 (0.77–1.03: 0.13) among men, and 0.83 (0.67–1.03: 0.40) among women. For distal gastric cancer, the multivariate HR for the highest quintile of total vegetable intake was 0.78 (0.63–0.97: 0.02) among men.

These reports all suggest that appropriate vegetable intake prevents obesity, CVD, and other lifestyle-related diseases. Thus, promoting vegetable intake among low-SES individuals worldwide is important for reducing health disparities.

2. Approaches to early risk reduction for lifestyle diseases

2-1. Individual factors related to vegetable intake

There are many reports by covariance structure analyses based on the theory of planned behavior (TPB) about the relationship between vegetable intake and health behavior. In one case, Blanchard et al. [26] examined that the utility of the TPB to explain the 5-A-Day intentions and behavior among undergraduate students in the southern United States (n=511, mean age = 19.8 years, SD 2.71). As a result, affective attitude and PBC were significant predictors of intention, which in turn was a significant predictor of behavior. Follow-up invariance analyses showed that none of the TPB relationships was moderated by gender or ethnicity. Thus, they suggested that TPB may be a useful framework on which to base a 5-A-Day intervention for undergraduate students from widely varying ethnic backgrounds.

In another case, Bogers et al. [27] examined the utility of TPB to explain fruit and vegetable intake among Dutch women (n=159, mean age 41 years). Their results also showed

that PBC is the strongest predictor of intentions and behavior, and they concluded that awareness of personal behavior should be taken into account to explain dietary behaviors (e.g., to provide practical methods on how to prepare fruit and vegetables in easy and quick ways).

Yet another example is Emanuel et al. [28], who investigated the possibility that gender differences in fruit and vegetable intake are attributable to gender differences in TPB. Women reported more favorable attitudes and greater PBC regarding fruit and vegetable intake than men, and these beliefs mediated the observed gender difference. Men reported greater perceived norms for fruit and vegetable intake, but these norms did not predict it. Therefore, interventions targeted at men may increase fruit and vegetable intake by promoting favorable attitudes and PBC among them.

In a third example, Kothe et al. [29, 30] reported the relationship between vegetable intake and TPB through intervention studies. Participants were randomly assigned to two levels of intervention frequency matched for intervention content (low frequency: 9 longer emails, n=92; high frequency: 27 short emails, n=102). Participants received TPB-based email messages for 30 days designed to increase fruit and vegetable intake. Messages targeted attitude, subjective norm, and PBC. As a result, when two groups with different frequencies were combined, fruit and vegetable intake increased by 0.83 servings per day after 30 days. Intention, attitude, subjective norm, and PBC also increased. However, in the case of the participants who received email messages promoting fruit and vegetable intake every three days over the course of the 30 days [30], significant increases in attitude and subjective norm relative to control were found. However, intention, PBC, and fruit and vegetable intake did not change as a result of the intervention, and hence it was not successful in increasing fruit and vegetable intake. Thus, even with a short-term intervention, there is a possibility of increasing vegetable intake by providing supportive messages frequently.

In a final example, Henry et al. [31] investigated the relationship between stage of change and decisional balance, processes of change, and self-efficacy variables of TTM (a concept similar to stage of change) to increase fruit and vegetable intake among low-income African-American mothers aged 18 to 45 years (n=420). They suggested increasing vegetable intake by nutrition education intervention focusing on improving self-efficacy (a concept similar to PBC). Thus, interventions to increase fruit and vegetable intake for women should include awareness of health benefits, thus increasing self-efficacy and improving people's ability to make plans and engage in healthy behavior.

2-2. Environmental factors related to vegetable intake

The relationship between the physical food environment and perception of it is discussed outside of Japan. However, definite conclusions have not yet been agreed on, so further research is needed on the determinants of perceptions of food environment to enhance our understanding of the drivers of socio-economic disparities in diet.

The first example of such a study is that by Blitstein et al. [32], who examined whether characteristics such as quality, selection, and convenience are associated with fruit and vegetable intake independent of perceived costs among low-income U.S. adults (n=495). Their results showed that more positive perceptions of the food-shopping environment were associated with more fruit and vegetables intake, and this association was independent of perceived cost, store type, and socio-demographic characteristics. The data also showed that among a generally minority and low-income population, quality, selection, and convenience are important determinants of fruit and vegetable intake. Therefore, nutrition promotion strategists should consider people's shopping environments.

Secondly, Williams et al. [33] examined whether objective measures of the food environment are associated with perceptions of it, and whether this relationship varies by levels of socio-economic disadvantage among Australian women. The study was cross-sectional (n=1,393 women aged 18 to 65 years). They found that socioeconomic disadvantage limited the relationship between the objective and the perceived environment, and that proximity to supermarkets and greengrocers may have a positive effect on perceptions and intake of healthy food. These results show that changing the price and availability of fruit and vegetables changes perceptions or intake of healthy food, so that nutrition education interventions targeting the environment should incorporate strategies to overcome negative perceptions about the cost and availability of fruit and vegetables. Therefore, it is important not only to improve the physical environment, but also to improve the perception of it.

In Japan, meanwhile, regional intervention studies from 2008 to 2011, Shimomitsu [34] showed environmental perception as an indicator in the development of concrete methods for resident-oriented food environment development. Through three years of municipally sponsored activities, improved access to food by opening grocery stores was done. Information was provided in conjunction with the improvement of the access to food, such as proactive public information association. Changes in the perception of the food environment over the three years showed little change in perception at the individual and family levels, but

perceptions of the food environment improved. These initiatives did not evaluate food intake or eating behaviors such as vegetable intake, so it is unclear whether improvement of environmental perception affects improvement of diet. In order to evaluate perception of food environments in Japan, it is worthwhile to verify the relationship between environment and desirable food intake.

Although reports in Japan are limited, Motohashi et al. [35] reported the possibility that high social capital and vegetable intake are positively related. They examined associations between interest in dietary pattern, social capital, and psychological distress by a cross-sectional study in rural Japan (n=11,658 aged 30-79 years). A high interest in dietary pattern was significantly associated with a high level of social capital. In addition, the study confirmed an association between interest in dietary pattern and frequency of fruit and vegetable intake. Therefore, high frequency of fruit and vegetable intake and high levels of social capital appear to be correlated.

There are some other studies targeting low-income people outside of Japan. In one instance, Flint et al. [36] investigated the extent to which perceptions of the quality, variety, and affordability of local food retail provision predict fruit and vegetable intake in the U.S. This study was cross-sectional (n=1, 263 aged 18 to 92 years), like most of the others. Flint took a random sample of households from two low-income Philadelphia neighborhoods. Their perceptions of their food environments were measured using five dimensions pertaining to quality, choice, and expense of local food outlets, and locally available fruits and vegetables. Their results suggest that the measured dimensions of perceived neighborhood food environment did not predict fruit and vegetable intake in low-income Philadelphians. However, further investigations are needed to conclude the relationship between vegetable intake and perception of food environment.

Additionally, Williams et al. [37] reported a pilot intervention that aimed to improve perceptions of healthy food affordability amongst mothers recruited from primary schools located in a socioeconomically disadvantaged suburb. The study was also cross-sectional (n=66). Results revealed that mothers in the intervention group perceived healthy food as more affordable than did those in the control group. Hence, nutrition education interventions to make people perceive healthy food as being “reasonably priced” may be a promising approach too.

2-3. Nutrition education programs based on behavioral science theory

Overall vegetable intake worldwide remains below recommended levels, despite evidence of its health benefits. Therefore, practical strategies for reducing disparities in vegetable intake between social groups are lacking, and urgently needed. Among researchers who have studied methods for increasing vegetable intake, Pomerleau et al. [38] reviewed published interventions (n=44) up to 2004, Thomson et.al. [39] reviewed published interventions (n=36) from 2005 to 2010, and Appleton et al. [40] reviewed published interventions (n=77) up to 2015. Pomerleau et al. [38] found that with primary prevention interventions in healthy adults, fruit and vegetable intake increased by approximately 0.1-1.4 servings per day. Thomson et al. [39] found that interventions involving minority adults or low-income participants of adults increase their average intake of fruit and vegetables +0.97 servings per day, and worksite interventions average +0.8 servings per day. These reviews suggest that achieving recommended levels of vegetable intake across the population cannot be achieved through behavior-based interventions alone. Thus, multi-component interventions using environmental, educational, and technological approaches to behavior change are needed to increase fruit and vegetable intake [40].

Some nutritional education interventions based on the TTM have been developed for employers. In Japan, Sawada et al. [41] conduct the study aimed at increasing vegetable intake in workplace cafeterias. This intervention program was based on the TTM, and lasted a period of 10 months. Sawada analyzed the intervention group (n=212) and the non-intervention group (n=359), both of which were recruited from a food factory. The main results showed that vegetable intake significantly increased in the intervention group (from 91.8g to 106.8g /1,000 kcal). This corresponded to a between-group difference of 14.2g /1,000 kcal (95% CI: 5.1-23.3; p=0.036).

In a similar study, Kushida et al. [42] used TTM to assess the effects of intervention on vegetable intake in 16 workplaces, half of which were subjected to intervention (n=8) while the other half were not (n=8). Participants were 349 Japanese male workers aged 20 to 59. For the intervention group, 12 table tents distributed TTM-based information on increasing vegetable intake for 24 weeks. The difference in the TTM between the two groups was not significant, but the intervention group (n=181) did increase its vegetable intake by +0.18 servings in the cafeteria, and +0.32 servings per day versus the comparison group (n=168).

Sawada et al. [43] also examined the effectiveness of nutrition education and environmental intervention in a worksite cafeteria with a quasi-experimental study. In that study, 596 employees completed a baseline survey. The intervention period was for three months. Of the valid respondents (n=123, both men and women), those with body mass index (BMI) (kg/m2) of 25 or higher and with waist circumferences of 85 centimeters or higher were selected as the direct study participants. The education and environment group (n=53) received TTM-based nutrition education sessions using video programs along with environmental intervention in the worksite cafeteria and canteens. Sawada found that only the education and environment group showed desirable behavioral changes in knowledge, self-efficacy, dietary behavior, and food or nutrient intake. They therefore suggested that the integration of nutritional education with environmental intervention result in desirable behavioral change.

Still another study of this type was Beresford et al. [44] evaluation of nutrition education in a worksite cafeteria by a nutrition intervention based on stages of change. They studied 28 worksites with cafeterias, and randomized intervention (n=14) and control (n=14) groups among them. Then he compared worksite fruit and vegetable intake with a two-year follow-up at baseline after the intervention effect of 0.3 servings per day.

There are also many reports of success in increasing vegetable intake by nutritional education intervention that integrated multiple behavioral science theories. However, some have pointed out that nutrition intervention might possibly widen dietary disparities. For example, Oldroyd et al. [5] reviewed interventions that aimed to promote healthy diets between 1990 and 2007. Two of these studies in his reviewed were conducted on adults with diverse ethnic and SES backgrounds. They focused on increasing fruit and vegetable intake, but their effect on disparity in vegetable intake was not determinable.

In a final example, Ball et al. [45] succeeded in increasing vegetable intake in individuals by nutrition education integrating multiple health behavioral theories. They investigated the costs and effects of a behavior change intervention for increasing fruit and vegetable purchasing and intake among socioeconomically disadvantaged women in Australia. This study was a RCT involving a three-month retrospective baseline data collection phase (time T0), a six-month intervention (T1-T2), and a six-month non-intervention follow-up (T3). The participants were randomly assigned to intervention (n=124) or to control (n=124). Participants in the intervention group reported significantly more vegetable intake during the intervention (T2) than did controls, with smaller intervention effects sustained at T3. Relative

to controls (n=108), vegetable intake increased by 0.5 servings per day from baseline to T2, and remained 0.28 servings higher per day than baseline at T3 among those who received the intervention (n=103). Thus, this behavioral intervention did increase vegetable intake among SES disadvantaged women. Further intervention research is needed, however, to establish whether nutrition education intervention can reduce social disparities in vegetable intake.

2-4. Web-based nutrition education programs

Internet technology is an advanced way of flexibly delivering messages. Before popularizing this method, however, it is important to investigate the potential of web-based tailored nutrition education. Oenema et al. [46], Bensley et al. [47], and Neuenschwander et al. [48] personally investigated the impact of web-based computer-tailored nutrition education on fruit and vegetable intake.

Firstly, Oenema et al. [46] conducted an RCT with a pre- and posttest control group design. They found significant differences in awareness and intention to change between the intervention and control groups in the post-test. Therefore, he estimates tailored intervention highly.

Secondly, Bensley et al. [47] compared the impact of Internet nutrition education to that of traditional nutrition education for fruit and vegetable intake. Interventions were done at 15 clinics after normal clinic operations, or delivered online. A total of 692 and 872 participants among U.S. women from eight agencies self-enrolled respectively in two phases from 2005 to 2007 at three-month intervals during a nine-month phase. Bensley's main results show that the Internet group experienced positive changes in stage of change progression, perception that the intervention was helpful and easy to use, and fruit and vegetable intake. Traditional nutrition education, by contrast, required follow-up counseling to achieve fruit and vegetable intake levels similar to the Internet nutrition education group. This suggests that Internet nutrition education is a viable method for increasing fruit and vegetable intake.

Thirdly, Neuenschwander et al. [48] examined whether web-based nutrition education could result in equivalent nutrition-related behavior outcomes when compared with traditional nutrition education in low-income American adults from April to December 2010. A sample of low-income adults was randomized to receive in-person education (n=66), or web-based education (n=57). The web-based group received three nutrition education lessons designed to replicate those received by the in-person group. Most nutrition-related behavior

outcomes (e.g., fruit and vegetables) improved significantly from pre- to postintervention for both groups, meaning that each intervention was effective. Furthermore, when the behavior improvements were compared between the groups, their changes were equivalent. Therefore, Neuenschwander suggested that web-based nutrition education can lead to favorable and equivalent nutrition-related changes when compared with face-to-face intervention.

As web based intervention have been attracting attention, many recent studies have reported increasing vegetable intake among adults. For example, Park et al. [49] evaluated a theory-based, Internet-delivered, RCT, treatment-control design nutrition education for young American adults aged 18 to 24 (n=160). The study's design also included pre- and postintervention assessments. A TTM-based Internet program, Fruit and Vegetable Express Bites, was delivered to intervention group participants; controls received non-tailored messages. The main results show that of baseline respondents, 86.5% completed the study. At follow-up (30 days), self-efficacy, decisional balance, and selected processes improved for both groups, with only marginal advantages for the theory-based version. Moreover, changes in fruit and vegetable intake were similar for both groups. Park therefore concluded that the Internet is a favorable tool to increasing vegetable intake for young adults.

In another Internet-based RCT study, Sternfeld et al. [50] conducted a 16-week e-mail program offering individually tailored nutrition programs in 2006. Participants (n=787) were employees in the administrative offices of a large healthcare organization who volunteered. The results showed increased fruit and vegetables intake (0.18 servings per day) in the intervention group. More importantly, differences between the intervention and control groups were still observed four months after the intervention ended.

In a third Internet-oriented RCT study, Alexander et al. [51] assessed change in fruit and vegetable intake in the U.S. by comparing an online untailored program (arm 1) with a tailored behavioral intervention (arm 2), and a tailored behavioral intervention and motivational interview-based counseling via e-mail (arm 3). Of 2,540 adults aged from 21 to 65, 80% were followed up after 12 months. Overall, the baseline mean for fruit and vegetable intake was 4.4 servings per day, with the greatest increase (2.8 servings) among arm 3 participants compared with the controls. Alexander concluded that this online nutritional intervention was well received, convenient, easy to disseminate, and associated with sustained dietary change.

In a final American study of web-based intervention, O'Donnell et al. [52] investigated the relationship between goal setting and fruit and vegetable intake in an intervention for college students aged 18 to 24. They analyzed the completed data (n=724) of the intervention group over a 10-week online intervention. Outcomes measured in number of cups of fruit and vegetables per day, and goals for both behaviors, were reported online each week. There was an increase in fruit and vegetable intake among the intervention group.

In contrast with America, web-based interventions in Japan have been very few. In one case, Imanaka et al. [53] reported a web-based intervention on weight management. Their RCT study aimed to compare the effects on weight change between those using a web-based self-disclosure health support system, and those using an email health support system. Participants (n=193) were randomly assigned to either the web-based self-disclosure health support system group (n=97), or the email health support group (n=96). Eligible participants were aged 35 to 65 years, and all had a BMI of ≥25.0 in their latest health examination. The follow-up period was 12 weeks for both groups. They found that weight loss was significantly greater in the web-based self-disclosure health support system group than in the health support system group (-1.6 kg vs -0.7 kg). However, there have been no reports in Japan of web-based nutrition education intervention that has a significant influence on weight management.

Worldwide, reporting on vegetable intake using web-based nutrition education intervention for socioeconomically disadvantaged groups is extremely limited. The main example is Buller et al. [54], who assessed how the 5-A-Day program on the Rio Grande Way website increased fruit and vegetable intake in a rural region enrolling 755 adult participants from 2002 to 2004. A total of 473 (63%) participants completed a four-month follow-up. Their change in fruit and vegetable intake was not significant, but the number who ate five or more daily servings of fruit and vegetables was higher at post-test in the intervention group (from 13.9% to 19.8%) than in the control group (from 17.4% to 13.8%). Buller concluded that a nutrition website may improve fruit and vegetable intake in a rural region. Although there are a few other reports on nutrition among socioeconomically disadvantaged groups and areas, there is no evidence for reduce social disparities in vegetable intake.

Ⅳ. General Purpose

I set up a research design aimed at reducing the health disparities accompanying vegetable intake levels among social groups. Our methods were as follows: 1) Formulate an intervention plan by means of a cross-sectional study to identify the relevant elements of the desired vegetable intake (individual and environmental perception). 2) Develop a web-based nutrition education intervention program with our intervention plan, including factors such as prescribing preferred vegetable intake. 3) Conduct a randomized controlled trial comparing the effect of a web-based nutrition education intervention program on different income groups to verify the reduction in the disparity of vegetable intake.

Study 1-1 aimed to investigate the prediction of a desirable level of vegetable intake with the structural relationships between various aspects of meals, then to investigate differences in the structural model due to household income and identify structures important for change in vegetable intake. If the model that best predicts intake of vegetables, and the characteristics of its constituent elements, differs depending on household income, this is a key piece of information that can contribute to the planning of nutrition education interventions according to household income level.

Study 1-2 aimed to determine whether food environment perceptions are a key factor for causing healthy vegetable intake and differences in it due to household income. It proposed to the participants that the key factor in effectively promoting vegetable intake is perception of their food environment.

Study 2 described the methods and protocol of a RCT based on behavioral science theory to verify the effectiveness of a web-based nutrition education program promoting vegetable intake among adults.

Study 3’s aim was to verify the reduction in the income-based disparity in vegetable intake by our web-based nutrition education program.

Ⅴ. Study 1-1: Differences by household income in predictors in a structural equation model of vegetable intake in Japanese adults

1. Background

Many studies have shown that appropriate vegetable intake is effective for preventing cancer [14, 15, 25], cardiovascular diseases [15, 17, 18], obesity [16], and other lifestyle-related diseases. Nevertheless, the lack of vegetable intake remains unresolved internationally. There are global health promotion strategies to promote vegetable intake, which is important regardless of generation or socioeconomic status.

Japan is the world's top country for longevity. In Japan, 350g of vegetables per day is the recommended intake to prevent lifestyle-related diseases in adults [20]. However, recent Japanese data have shown that the vegetable intake of 2/3 of adults is below this level, and the variation by household income is remarkable [21]. Nakamura [23] showed that the lower the household income, the lower the vegetable intake, and that specifying the factors related to vegetable intake is the next task for reducing this disparity in vegetable intake. The planning of an intervention program depending on household income level is important in order to improve low vegetable intake among Japanese people.

The Japanese Food Guide Spinning Top [55] is composed of dish units such as ‘grain dishes,’ ‘fish and meat dishes,’ ‘vegetable dishes,’ and so on. The intake target of the Food Guide Spinning Top distinguishes vegetables (5 serving (SV)) from fruits (2 SV) [55]. In recent years, the Japan Public Health Center-based Prospective Study (JPHC) has reported that closer adherence to Japanese dietary guidelines is associated with a lower risk of total mortality and mortality from cardiovascular disease, particularly from cerebrovascular disease, among Japanese adults [56]. It is reported that the higher the frequency of meals consisting of grain dishes, fish and meat dishes, and vegetable dishes, the higher the vegetable intake, and additionally, the better the intake of nutrients [57]. Meals consisting of grain dishes, fish and meat dishes, and vegetable dishes are traditional ‘Japanese dietary style,’ and the recommendation policy that distinguishes fruits and vegetables is characteristic of Japan. Structurally organizing the interrelationships among constituent elements of dietary habits is important in the planning of a nutrition education intervention that promotes the transformation of behavior relating to desirable vegetable intake, taking into consideration the eating habits of the country. However, in an intervention plan aiming to increase intake of

vegetables, mutual relationships among variables including aspects of meals other than vegetables have not been clarified.

A health education intervention with the outcome of transformation of eating behaviors must preparation factors in behavioral change, such as Attitude, Subjective Norm, PBC (a concept similar to self-efficacy), and so on. The Stage of Change, which is positioned as a factor in preparation for action [58] or an intermediate factor [59], is the most commonly used concept in health education intervention in Japan. In previous researches, mutual relations among variables have been investigated using structural equation modellings or path analyses based on behavioral science theory to predict behavioral change in vegetable intake. For example, there are several prior studies on the relationship between vegetable intake and the TPB [26-30]. Furthermore, in health education interventions, it has been pointed out that the use of multiple concepts may effectively promote a change in desirable dietary habits [38-40]. Therefore, structurally examining the interrelationships of multiple concepts makes it possible to predict important concepts and essential elements at the time of a health education intervention, leading to effective results.

If the model that best predicts intake of vegetables and the characteristics of its constituent elements differs depending on household income, this will be a key piece of information that can contribute to the planning of nutrition education interventions according to household income level. The purpose of this study was to investigate the concept of predicting desirable vegetable intake and the structural relationships between aspects of meals, and subsequently to investigate differences in the structural model due to household income and identify structures important for behavioral change in vegetable intake.

2. Methods

2-1. Participants and procedure

This survey employed a cross-sectional study design and was a multipurpose investigation based on a field survey of Japanese SES and dietary habits. In February 2014, an Internet-based cross-sectional survey was conducted by a Japanese online research service company that holds data, including sociodemographic attributes, for approximately 160,300 registered adults aged 30–59 years. Details of the method have been previously published [23]. Thus, I targeted middle-aged adults, because health promotion, healthy eating, and reducing health disparities are particularly important in this age group. The sample size and attributes

were stratified according to the Japanese age distribution, and using the 2013 Population Census of Japan for sex and age [60] and the 2012 Comprehensive Survey of Living Conditions in Japan for household income [61]. In total, 8,284 adults were randomly selected, which were matched to the Japanese population statistics from the database, and they received an e-mail inviting them to participate. The e-mail contained a URL for a protected area of the website in which the questionnaire was located, and they could log on using an ID number and password. The research service company offered reward points valued at 100 JPY (one USD was approximately 102 JPY in February 2014). I collected data from 3,269 adults within the investigation period. Respondents who completed the questionnaire and clicked the send button at the end of the online informed consent form were considered to have consented to participation. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the Ethics Review Committee on Research with Human Subjects of Waseda University, Japan (2013-249).

2-2. Socioeconomic status and sociodemographic variables

The household income was obtained as categorical data using the following levels: < 3,000,000 JPY, 3,000,000–5,000,000 JPY, 5,000,000–7,000,000 JPY, 7,000,000–10,000,000 JPY, 10,000,000–15,000,000 JPY, and > 15,000,000 JPY. For the analysis, household income was categorized as < 3,000,000 JPY, 3,000,000–7,000,000 JPY, and > 7,000,000 JPY [61]. Educational level was classified into three categories: junior high/high school, 2-year college, and 4-year college/graduate school. Demographic variables included sex, age, marital status, residence status, and employment status. Age was classified as 30–39, 40–49, and 50–59 years. Marital status was categorized as currently married or currently unmarried. Residence status was categorized as living with others or living alone. Employment status was categorized as employed or not employed.

2-3. Vegetable intake

5 SV of vegetables (5 small dishes/day, or about 350g) is the minimum vegetable intake to aim for to prevent disease or to maintain health [62]. The questionnaire items concerning vegetable intake, which were created by the Ministry of Health, Labor, and Welfare [63], were preceded by the following statement: 'The following questions are about your normal

meals.' Respondents were asked, ‘Do you eat adequate amounts of vegetables (five servings (350g) of vegetables per day)?’ Responses included four choices: (1) Always, (2) Sometimes, (3) Rarely, and (4) Never. Those who responded (1) or (2) to this question were considered to eat sufficient vegetables (yes), and those who responded (3) or (4) were considered to eat insufficient vegetables (no).

2-4. Assessment of other variables

Attitude, Subjective Norm, and PBC are factors that play an important role in behavioral change. In the population health planning of a health education intervention, they are positioned as predisposing, reinforcing, and enabling factors that affect behavior [64]. Stage of Change is positioned as a factor for preparation factors [58], or intermediate factor [59], and is an evaluation item for health education interventions in Japan. For each of these concepts, participants were asked about the following four items, to give a total of 20 items: 'having a meal consisting of grain dishes, fish and meat dishes, and vegetable dishes not less than twice a day,' 'eating vegetable dishes (dishes made mainly from vegetables or potatoes) not less than twice a day,' 'eating green/yellow vegetables not less than once a day,' and 'eating fruits not less than once a day.' These items were selected from factors predicting a desirable diet [65]. Participants answered the items as shown in Table 1. Responses for Stage of Change, Attitude, Subjective Norm, and PBC were classified into two categories (relatively positive answers = 1, negative answers = 0), because the answers were biased in dispersion, taking into consideration the contents and distribution of the answers.

2-5. Statistical analysis

Data were analyzed for 3,137 adults who provided complete information for the variables. Respondents who did not provide information regarding educational (other/unknown, n = 52) or employment status (other/unknown, n = 80) were not included. Interpretation of the results would have been difficult if other/unknown responses were combined with the other choices because there were very few of these responses. Statistical analysis was performed separately for household income. The associations between the characteristics and vegetable intake were analyzed using the $\chi 2$-test. I examined the Cronbach's alpha coefficients of the four items for the variables by factor analysis (Table 1).

I performed a multiple group structural equation modelling to identify vegetable intakes as behavior predictors. The advantage of structural equation modelling is that it can be used to analyze complex relationships among independent variables that may explain eating vegetables, and can show both direct and indirect effects on dependent variables. First, all direct paths from the independent variables to the dependent variable, and paths among independent variables indicated. Next, I created a model was revised in reference to the modification index and a goodness-of-fit index, and the most adaptable was adopted as the best model. All statistical analyses were performed using IBM SPSS v. 20 software (IBM, Tokyo, Japan). Structural equation modellings were conducted using the Amos software (v. 20; IBM, Tokyo, Japan). Three additional goodness-of-fit indices were calculated: the NFI, CFI, and RMSEA. All path coefficients were standardized estimates. Statistical significance was set at $p < 0.05$.

3. Results

The Cronbach's alpha values for each construct, shown in Table 1, were as follows: Stage of Change, 0.84; Attitude, 0.80; Subjective Norm, 0.93; and PBC, 0.86.

Table1. Questionnaire about diet component to predict vegetable intake behavior

Variable	Diet component in the questionnaire	Answer category
Stage of Change		
(†four items; α=0.84)	1. To have a meal consisting of grain dishes,fish and meat dishes and vegetable dishes not less than twice a day.	1. Maintenance (I continue to eat for more than 6 months)
	2. To eat vegetable dishes (dishes made mainly from vegetables or potatoes) not less than twice a day.	2. Action (I continue to eat for less than 6 months)
	3. To eat green/yellow vegetables not less than once a day.	3. Preparation (I eat sometimes or intend to eat within the next 30 days)
	4. To eat fruits not less than once a day.	4. Contemplation (Although I do not eat, I intend to start eating within the next 6 months)
		5. Precontemplation (I do not eat and I do not intend to start eating within the next 6 months)
Attitude		
(†four items; α=0.80)	1. To have a meal consisting of grain dishes,fish and meat dishes and vegetable dishes not less than twice a day.	1. A lot of important (I think it to be very important)
	2. To eat vegetable dishes (dishes made mainly from vegetables or potatoes) not less than twice a day.	2. Quite important (I think it to be quite important)
	3. To eat green/yellow vegetables not less than once a day.	3. A little important (I think it to be a little important)
	4. To eat fruits not less than once a day.	4. Not a lot of important (I do not think it to be very important)
		5. Quite important (I think it to be little important)
		6. A little important (I do not think it to be important at all)
Subjective Norm		
(†four items; α=0.93)	1. To have a meal consisting of grain dishes,fish and meat dishes and vegetable dishes not less than twice a day.	1. Strongly Agree (I think it to be strong agree)
	2. To eat vegetable dishes (dishes made mainly from vegetables or potatoes) not less than twice a day.	2. Agree (I think it to be agree)
	3. To eat green/yellow vegetables not less than once a day.	3. Disagree (I do not think it to be agree)
	4. To eat fruits not less than once a day.	4. Strongly Disagree (I do not think it to be agree at all)
Perceived Behavioural Contorol		
(†four items; α=0.86)	1. To have a meal consisting of grain dishes,fish and meat dishes and vegetable dishes not less than twice a day.	1. A lot of confidence (I have a lot of confidence in eating)
	2. To eat vegetable dishes (dishes made mainly from vegetables or potatoes) not less than twice a day.	2. Quite confidence (I have quite confidence in eating)
	3. To eat green/yellow vegetables not less than once a day.	3. A little confidence (I have a little confidence in eating)
	4. To eat fruits not less than once a day.	4. Not have a lot of confidence (I do not have a lot of confidence in eating)
		5. Littele confidence (I have little confidence in eating)
		6. Not have any confidence (I do not have any confidence in eating)

†Each variable item was examined by calculating the factor structure with a principal component analysis and Cronbach's alpha.

Overall mean age was 44.1 (SD = 8.1) years. Approximately half of the respondents were women (49.6%; Table 2). For all household incomes, among those with desirable vegetable intake, there was a higher proportion of women than of men, of people living together than not living together, and of employed people than of those not employed. Moreover, common to the three household income categories was the finding that for most of the ‘Stage of Change,’ ‘Attitude,’ ‘Subjective Norm,’ and ‘PBC’ items, there was a higher proportion of positive answers to each of the four items in those who met the desirable vegetable intake than in those who did not (Table 3).

Table2. Characteristics of the Japanese adult participants in each household income category

		<3,000,000 yen[¶]					3,000,000 -7,000,000 yen[¶]					>7,000,000 yen[¶]				
		Vegetable intake[‡]					Vegetable intake[‡]					Vegetable intake[‡]				
		Yes n= 345		No n= 639		p[†]	Yes n= 630		No n= 663		p[†]	Yes n= 478		No n= 382		p[†]
		n	%	n	%		n	%	n	%		n	%	n	%	
Sex																
	Men	151	43.8	350	54.8	**	270	42.9	374	56.4	**	210	43.9	225	58.9	**
	Women	194	56.2	289	45.2		360	57.1	289	43.6		268	56.1	157	41.1	
Age	(years)															
	30-39	110	31.9	233	36.5		201	31.9	242	36.5		147	30.8	139	36.4	*
	40-49	128	37.1	219	34.3		227	36.0	237	35.7		164	34.3	142	37.2	
	50-59	107	31.0	187	29.3		202	32.1	184	27.8		167	34.9	101	26.4	
Marital status																
	Not married[§]	216	62.6	472	73.9	**	177	28.1	212	32.0		79	16.5	93	24.3	**
	Married	129	37.4	167	26.1		453	71.9	451	68.0		399	83.5	289	75.7	
Residence status																
	Not living together	107	31.0	249	39.0	*	47	7.5	106	16.0	**	17	3.6	29	7.6	**
	Living together	238	69.0	390	61.0		583	92.5	557	84.0		461	96.4	353	92.4	
Employment status																
	Not employed	130	37.7	189	29.6	**	175	27.8	151	22.8	*	125	26.2	59	15.4	**
	Employed	215	62.3	450	70.4		455	72.2	512	77.2		353	73.8	323	84.6	
Educational status																
	Junior high/high school	107	31.0	265	41.5	**	161	25.6	186	28.1		46	9.6	65	17.0	**
	2-years college	90	26.1	171	26.8		184	29.2	202	30.5		137	28.7	82	21.5	
	4-years college/graduate school	148	42.9	203	31.8		285	45.2	275	41.5		295	61.7	235	61.5	

*$p < 0.05$; **$p < 0.01$.

[†]The associations between the characteristics and vegetable intake were analysed using the $\chi 2$-test.

[‡]Responses were provided on a scale with four options: (1) always, (2) occasionally, (3) rarely, and (4) never. Subjects who chose (1) or (2) were considered to have answered positively, and those who chose (3) or (4) were considered to have answered negatively. Responses for the dependent variable of vegetable intake were categorised as positive (yes) or negative (no).

[§]Not married: single, separated, or divorced.

[¶]One USD was equivalent to approximately 102 JPY in February, 2014.

Table3. Diet component to predict vegetable intake variables by household income category

		<3,000,000 yen[¶]					3,000,000 -7,000,000 yen[¶]					>7,000,000 yen[¶]				
		Vegetable intake[‡]					Vegetable intake[‡]					Vegetable intake[‡]				
		Yes n= 345		No n= 639		p[†]	Yes n= 630		No n= 663		p[†]	Yes n= 478		No n= 382		p[†]
		n	%	n	%		n	%	n	%		n	%	n	%	
Stage of Change																
To have a meal consisting of grain dishes, fish and meat dishes and vegetable dishes	Maintenance/Action[§]	204	59.1	166	26.0	**	403	64.0	246	37.1	**	318	66.5	155	40.6	**
	Other	141	40.9	473	74.0		227	36.0	417	62.9		160	33.5	227	59.4	
To eat vegetable dishes	Maintenance/Action	213	61.7	149	23.3	**	379	60.2	195	29.4	**	317	66.3	132	34.6	**
	Other	132	38.3	490	76.7		251	39.8	468	70.6		161	33.7	250	65.4	
To eat green/yellow vegetables	Maintenance/Action	238	69.0	142	22.2	**	443	70.3	195	29.4	**	358	74.9	139	36.4	**
	Other	107	31.0	497	77.8		187	29.7	468	70.6		120	25.1	243	63.6	
To eat fruits	Maintenance/Action	172	49.9	155	24.3	**	323	51.3	167	25.2	**	274	57.3	117	30.6	**
	Other	173	50.1	484	75.7		307	48.7	496	74.8		204	42.7	265	69.4	
Attitude																
To have a meal consisting of grain dishes, fish and meat dishes and vegetable dishes	Very/quite/a little important	315	91.3	523	81.8	**	597	94.8	601	90.6	**	444	92.9	343	89.8	
	Other	30	8.7	116	18.2		33	5.2	62	9.4		34	7.1	39	10.2	
To eat vegetable dishes	Very/quite/a little important	321	93.0	513	80.3	**	588	93.3	583	87.9	**	449	93.9	336	88.0	**
	Other	24	7.0	126	19.7		42	6.7	80	12.1		29	6.1	46	12.0	
To eat green/yellow vegetables	Very/quite/a little important	332	96.2	555	86.9	**	611	97.0	606	91.4	**	464	97.1	350	91.6	**
	Other	13	3.8	84	13.1		19	3.0	57	8.6		14	2.9	32	8.4	
To eat fruits	Very/quite/a little important	294	85.2	485	75.9	**	549	87.1	539	81.3	**	416	87.0	297	77.7	**
	Other	51	14.8	154	24.1		81	12.9	124	18.7		62	13.0	85	22.3	
Subjective Norm																
To have a meal consisting of grain dishes, fish and meat dishes and vegetable dishes	Strongly Agree	106	30.7	93	14.6	**	188	29.8	117	17.6	**	146	30.5	62	16.2	**
	Other	239	69.3	546	85.4		442	70.2	546	82.4		332	69.5	320	83.8	
To eat vegetable dishes	Strongly Agree	106	30.7	85	13.3	**	178	28.3	113	17.0	**	145	30.3	47	12.3	**
	Other	239	69.3	554	86.7		452	71.7	550	83.0		333	69.7	335	87.7	
To eat green/yellow vegetables	Strongly Agree	115	33.3	102	16.0	**	207	32.9	131	19.8	**	179	37.4	70	18.3	**
	Other	230	66.7	537	84.0		423	67.1	532	80.2		299	62.6	312	81.7	
To eat fruits	Strongly Agree	89	25.8	87	13.6	**	162	25.7	88	13.3	**	132	27.6	47	12.3	**
	Other	256	74.2	552	86.4		468	74.3	575	86.7		346	72.4	335	87.7	
Perceived Behavioural Contorol																
To have a meal consisting of grain dishes, fish and meat dishes and vegetable dishes	A lot of/quite/a little confidence	258	74.8	190	29.7	**	480	76.2	278	41.9	**	388	81.2	180	47.1	**
	Other	87	25.2	449	70.3		150	23.8	385	58.1		90	18.8	202	52.9	
To eat vegetable dishes	A lot of/quite/a little confidence	262	76.0	181	28.0	**	472	75.0	258	39.0	**	388	81.0	170	45.0	**
	Other	83	24.1	458	71.7		158	25.1	405	61.1		90	18.8	212	55.5	
To eat green/yellow vegetables	A lot of/quite/a little confidence	281	81.4	199	31.1	**	512	81.3	268	40.4	**	418	87.4	184	48.2	**
	Other	64	18.6	440	68.9		118	18.7	395	59.6		60	12.6	198	51.8	
To eat fruits	A lot of/quite/a little confidence	225	65.2	237	37.1	**	415	65.9	260	39.2	**	361	75.5	171	44.8	**
	Other	120	34.8	402	62.9		215	34.1	403	60.8		117	24.5	211	55.2	

*p < 0.05; **p < 0.01.

†The associations between the characteristics and vegetable intake were analysed using the $\chi 2$-test.

‡Responses were provided on a scale with four options: (1) always, (2) occasionally, (3) rarely, and (4) never. Subjects who chose (1) or (2) were considered to have answered positively, and those who chose (3) or (4) were considered to have answered negatively. Responses for the dependent variable of vegetable intake were categorised as positive (yes) or negative (no).

§'Maintenance' means continuing to eat for more than 6 months. 'Action' means continuing to eat for less than 6 months.

¶One USD was equivalent to approximately 102 JPY in February, 2014.

The indices of fit for the tested model indicated an acceptable fit (NFI = 0.95, CFI = 0.96, RMSEA = 0.038). In multiple group structural equation modeling, for a household income of less than 3,000,000 JPY (Figure 1), Vegetable intake as behavior was directly affected by Stage of Change (coefficient = 0.20) and PBC (0.16). Stage of Change was directly affected by Attitude (0.09), Subjective Norm (0.15), and PBC (0.60). For a household income of 3,000,000–7,000,000 JPY (Figure 2) and more than 7,000,000 JPY (Figure 3), Vegetable intake as behavior was directly affected by Stage of Change (0.25 and 0.22 respectively). Stage of Change was directly affected by Attitude (0.06 and 0.10 respectively), by Subjective Norm (0.14 and 0.21 respectively), and by PBC (0.58 and 0.57 respectively). However, eating vegetables was not directly affected by PBC.

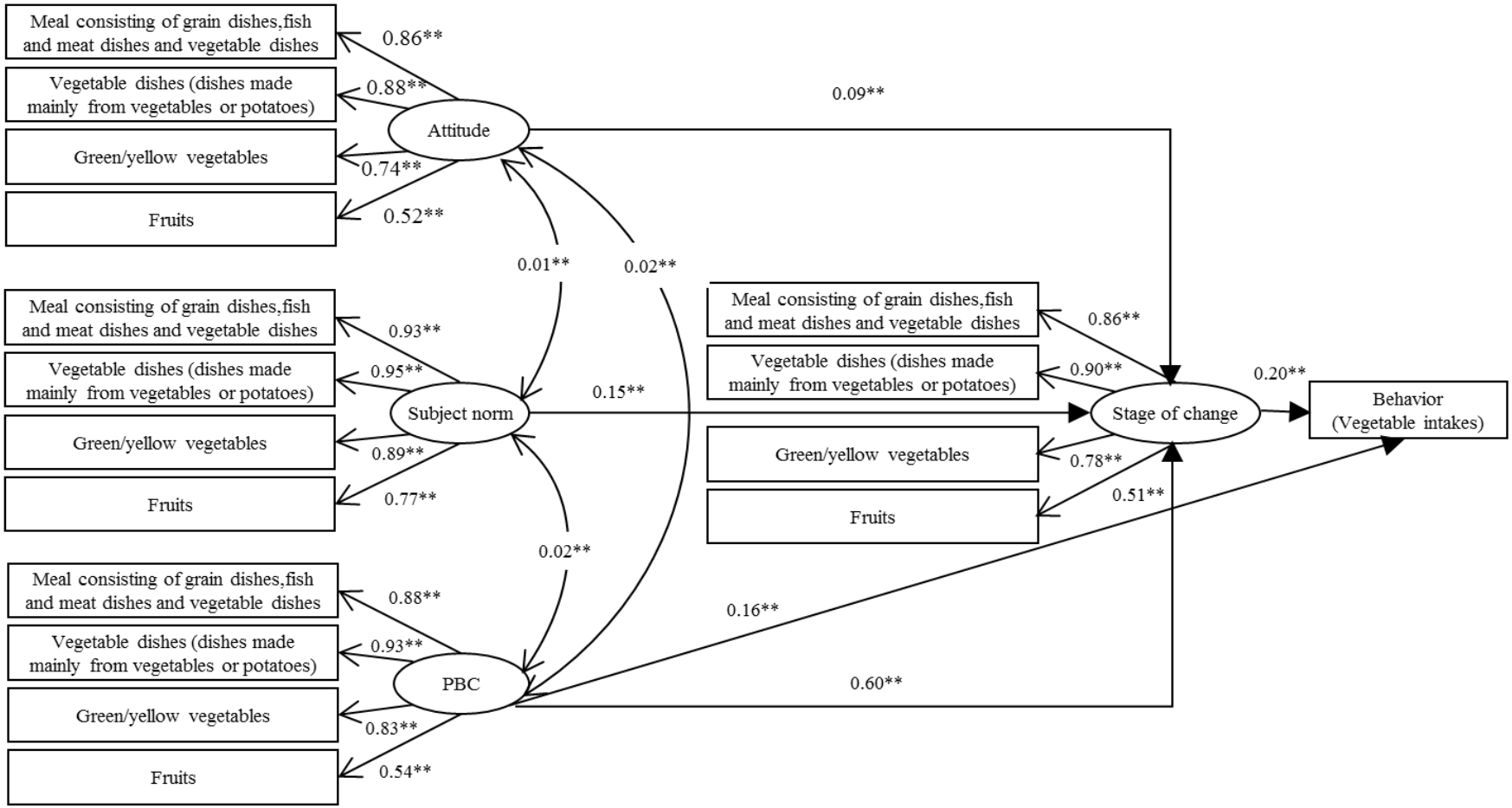

Figure 1. Path analysis for participation in diet component to predict vegetable intake behavior by household income: < 3,000,000 yen. All path coefficients were standardised estimates. Solid line represents significant path (*p < 0.05, **p < 0.01). PBC; Perceived behavioural control.

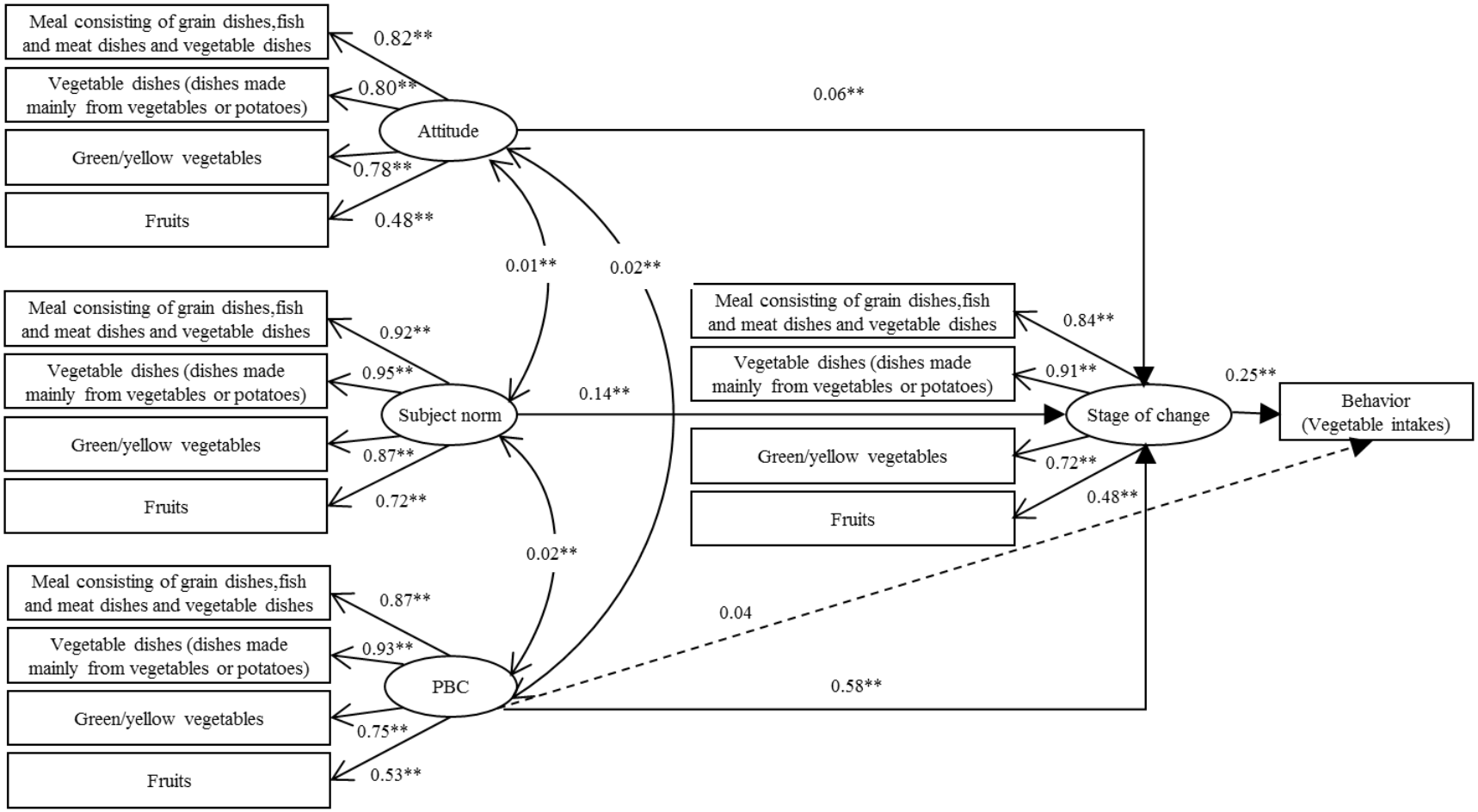

Figure 2. Path analysis for participation in diet component to predict vegetable intake behavior by household income: 3,000,000- 7,000,000 yen. All path coefficients were standardised estimates. Dotted line represents no significant path, and solid line represents significant path (*$p < 0.05$, **$p < 0.01$). PBC; Perceived behavioural control.

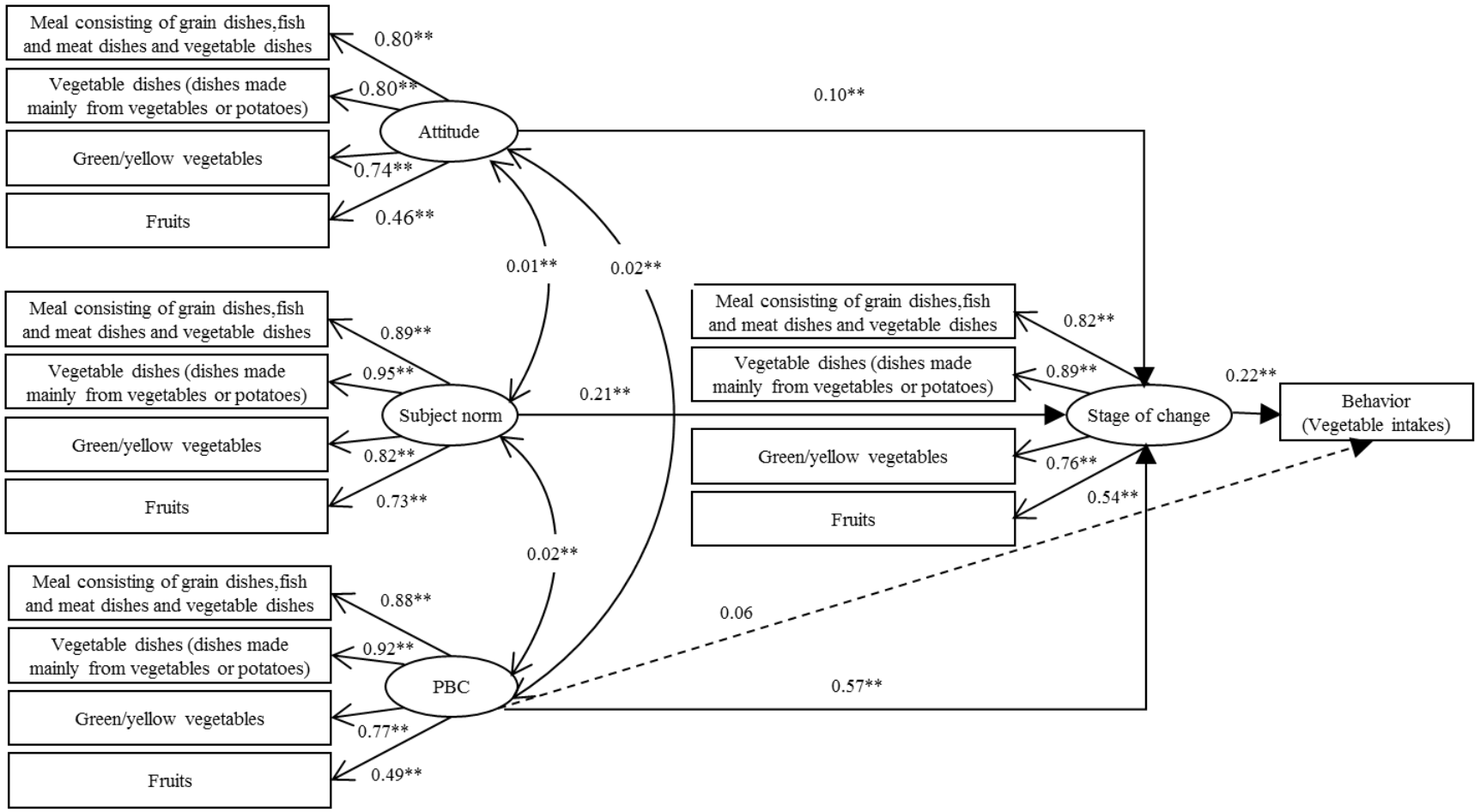

Figure 3. Path analysis for participation in diet component to predict vegetable intake behavior by household income: > 7,000,000 yen.
All path coefficients were standardised estimates. Dotted line represents no significant path, and solid line represents significant path (*p < 0.05, **p < 0.01). PBC; Perceived behavioural control.

4. Discussion

4-1. Main Discussion

To the best of our knowledge, this is the first study to structurally examine the relationships between several factors that predict vegetable intake among Japanese adults. The main findings common to any household income category were as follows. A variable with a strong possibility of predicting behavioral change in vegetable intake via Stage of Change was PBC. Dietary factors likely to predict Stage of Change of vegetable intake were not only vegetables and fruits but also included eating in a 'dietary pattern' consisting of staple food, a main dish, and side dishes. Therefore, strengthening PBC using a key element of the Japanese dietary pattern might help to promote behavioral change by increasing the Stage of Change of vegetable intake for a wide range of household incomes.

As a result of examining the internal consistency among predictors of vegetable intake, I found latent variables composed of 4 items (eating a meal consisting of grain dishes, fish and meat dishes, and vegetable dishes; eating vegetable dishes; eating green/yellow vegetables; and eating fruits); when these 4 items were analyzed in the model, high levels of internal consistency were observed. Therefore, to predict the desired vegetable intake, four dietary factors were required.

Stage of Change was a direct predictor of behavior, PBC was a direct predictor with the greatest influence over Stage of Change; this was common to the models for all household incomes. Furthermore, it was observed that PBC was a direct predictor of behavior only for the lowest household income category. PBC in this group was lower than Attitude and Subjective Norm, so there is much room for improvement. So there is a possibility that this lowest income group was observed only. Henry [31] reported success in improving PBC and increasing vegetable intake through a nutrition education intervention using behavioral techniques to improve self-confidence in low-income adult women. Therefore, when conducting nutrition education interventions for a group including those with a low income in Japan, a health education program with enhanced PBC improvement may be proposed. In contrast, Kothe [29] and Blanchard [26] targeting college students, have pointed out that based on covariance structure analysis, PBC is not a direct predictor of vegetable intake as behavior. These results are consistent with the results in the present study for the middle and high income groups. Differences in the relationship between PBC and behavior may be produced by variation in household income. Further studies in the field are needed to see whether

intervention programs focused on PBC can reduce the disparity in vegetable intake due to household income.

An interesting point of this research is that behavioral change in vegetable intake is influenced by Japan's unique ‘dietary pattern,’ with meals consisting of grain dishes, fish and meat dishes, and vegetable dishes. An original aspect of this research is the use of a structural representation of mutual relations among several elements: that is, not only items directly indicating vegetables (side dishes and green vegetables), but also those relating to Japan's unique ‘dietary pattern’ with meals consisting of grain dishes, fish and meat dishes, and vegetable dishes. Factors related to dietary patterns and food intake and mortality rate have already been discussed in cohort studies [56] and cross-sectional studies [57]. Because the importance of ‘dietary pattern’ rather than a single dish is attracting attention. Our study structurally examined the process of behavioral change with respect to desirable vegetable intake. Therefore, it was possible to show in detail the important concepts and relationships for the planning of a nutrition education intervention. With such a structural verification, I can plan a nutrition education program that will strengthen important factors in the future.

4-2. Limitations and implications

A strength of our study was that I structurally examined the relationships between vegetable intake as a behavior and various factors. By taking this approach, it is possible to identify important factors for the planning of nutrition education interventions. Furthermore, a sufficient sample size that matched distributions of sex, age, and household income to the actual Japanese demographic distributions was also an advantage. However, this study had some limitations. First, this study did not investigate objective indicators of vegetable intake (e.g., dietary records). Our study focused on ‘vegetables’ as a ‘behavior’ based on Japanese dietary habits. I must pay close attention to this when comparing our findings with other countries’ reports. Second, our sample might not represent the general Japanese population, because I conducted an Internet-based survey. An advantage of an Internet-based survey is that it is possible to use matched sampling with Japanese population statistics [60, 61] and random sampling from the survey company's participant. However, Internet-based survey respondents are more likely to have certain characteristics, such as being younger, having higher levels of education and income, and having better access to the Internet [66-68]. I must be cautious in generalizing the results. Third, this study did not use a structural model based on existing

behavioral science theory. I created a structure for predicting vegetable intake independently by combining multiple concepts from behavioral science theory. Investigating whether or not it can be applied to existing behavioral science theory [26-30], as in previous research, is a future task. For example, methods adopting behavioral techniques to enhance PBC [69].

VI. Study 1-2: Perceptions of neighborhood food environment predicting vegetable intake based on household income in Japanese adults: a cross-sectional study

1. Background

Japan has one of the highest levels of longevity in the world. Cardiovascular disease risk and obesity are lower than in other countries [10]. This positive health profile may due in part to Japan's unique dietary habits, which are drawing worldwide attention. Nevertheless, individuals within low- SES ranges consume very few vegetables. In Japan, the National Health and Nutrition Survey reported that low-income households consume few vegetables (i.e., highest-income bracket: men 322g, women 314g; lowest-income bracket: men 254 g, women 282 g), and the lower the income, the higher the obesity rate [21] (i.e., lowest-income: men 38.8%, women 26.9%; highest-income: men 25.6%, women 22.3%). Recently, income disparities are affecting various dietary behaviors in Japan [23], as well as mortality risk [13]. Health disparities are an increasing social problem [11]. Several studies have shown that appropriate vegetable intake is effective for cancer prevention [14, 15, 25] while also reducing risks for cardiovascular [15, 17, 18], obesity [16] and other lifestyle-related diseases. Hence, to help alleviate early disease risk and further reduce health disparities, promoting vegetable intake among low-SES individuals is an important worldwide issue.

Supporters of health promotion in neighboring areas, such as municipalities and corporate enterprises, need to conduct population-based approaches in order to encompass socioeconomically disadvantaged groups [21]. The preseed-proseed model has revealed a mutual relationship between health behavior and the environment [64]. In the case of dietary habits, the neighborhood food environment is a key factor. Previous research has reported that improving not only the physical food environment but also the perception of the food environment plays an important role in creating positive dietary habits [32, 70-72]. Moreover, there is a possibility that that the association between the perceived neighborhood food environment and vegetable intake could differ by household income [33]. In order to provide support for health promotion efforts that encourage desirable vegetable intake across the by income disparities, it is necessary to fully interrogate the interrelationships among these factors of neighborhood food environmental.

In Japan, efforts to improve food environments are currently underway, including the Dietary Reference Intakes for Japanese, which set habitual target values and dietary guidelines that account for consumer dietary styles. There is also the Japanese Food Guide Spinning Top, which provides idealized eating habits based on dish units. Shimomitsu [34] assessed aspects of Japanese food environments, specifically social capital within residential areas. Results revealed that improved food environment recognition, such as food accessibility within neighboring areas and access to information, was highly beneficial. However, only one city was under investigation, limiting the generalizability of those findings. Secondly, that prior work was unable to account for household income as SES among the participant sample.

In order to address the aforementioned limitations in Shimomitsu's [34] prior work, the present study was conducted to address the role of SES indicators on food environment perceptions and vegetable intake in Japan. The main aim of this study was to determine whether food environment perceptions are a key factor necessary for promoting healthy vegetable intake, and differences due to household income.

2. Methods

2-1. Study sample

I conducted a cross-sectional study, with a multipurpose investigation as to the dietary habits of Japanese adults. In February 2014, an Internet-based survey was administered among aged 30–59 years through an online research service company. Details of the methodology were published in a previous report [23]. Thus, participants were stratified according to age, gender [60] and household income [61] sampling matching socio-economic distributions in Japan. The survey request was delivered to 8,284 people extracted from approximately 160,000 people in the whole registered monitor in consideration of the response rate. I recruited a sample of approximately 3,000 adults, aged 30–59 years (500 men and 500 women from three age groups: 30–39, 40–49, and 50–59 years). I targeted this age group because the promotion of healthy eating, and a reduction in health disparities, is particularly important within this age range. In addition, students in their 20 years excluded this age because it is difficult to interpret socioeconomic status such as household income and education [23]. 8,284 adults were randomly selected from the database and received an e-mail inviting them to participate in the survey. The invitation e-mail contained a URL for a protected website in which the questionnaire was located. A total of 3,269 adults completed the

survey. Respondents who completed the survey and clicked the “Send” button after reading an online informed consent form were considered to have consented to participate. The research service company offered reward points, valued at 100 JPY (102 JPY = $1 USD in February 2014), for participating. This study was approved by the Ethics Review Committee on Research with Human Subjects of Waseda University, Japan (2013-249).

2-2. Socioeconomic status and sociodemographic variables

I was unable to accurately determine individual-level equivalent incomes, as categories for household income were as follows: < 3,000,000 JPY, 3,000,000–5,000,000 JPY, 5,000,000–7,000,000 JPY, 7,000,000–10,000,000 JPY, 10,000,000–15,000,000 JPY, and > 15,000,000 JPY. Therefore, I analyzed household income using three, equally distributed categories: < 3,000,000 JPY; Low, 3,000,000–7,000,000 JPY; Middle, and > 7,000,000 JPY; High [61]. This is the category I used to divide into three Japanese population distributions. Education level was classified into three categories: junior high/high school, 2-year college, and 4-year college/graduate school. Demographic variables included gender, age group, marital status, residential status, and employment status.

2-3. Vegetable intake

The questionnaire items concerning vegetable intake [63] were as follows: “The following questions are about your normal meals.” Respondents were asked, “Do you eat adequate amounts of vegetables (5 small dishes/day, or about 350 g)?” Responses included the following four choices: (1) Always, (2) Sometimes, (3) Rarely, and (4) Never. Those who responded (1) or (2) had sufficient vegetable intakes; Yes, those who responded (3) or (4) had insufficient vegetable intake; No.

2-4. Perception of neighborhood food environment

I evaluated 6 items included food access, food information access and food social capital as regarding perception of neighborhood food environment [34]. The instructions to participants on items concerning perception of neighborhood food environment were as follows: “Some questions about the people and where you live in (Elementary school and junior high school area boundaries in the municipalities). Please choose the most applicable of the following items: “Nutritionally balanced foods and menus are available at a nearby restaurant,

grocery store, and workplace cafeteria" (Availability of balanced meals); "Nutritionally balanced foods can be purchased at an reasonable price" (Reasonable prices for balanced foods); "Nutrition labels, such as those containing calorie information, are readily available and useful at nearby restaurants and grocery stores" (Nutrition labels at restaurants and grocery store information); "Daily shopping can be done within walking distance of the home" (Daily shopping within walking distance); "My neighborhood has an atmosphere of cherishing food culture, traditions, and seasonality"(Atmosphere of cherishing the food culture in my neighborhood); and "My neighborhood has the atmosphere of feeling free to exchange food with each other, such as bartering for food" (Atmosphere of feeling free to exchange food with each other in the neighborhood). Responses to these items were on the following scale: (1) Strongly agree; (2) Agree; (3) Neutral; (4) Disagree; and (5) Strongly disagree. Those who responded (1) or (2) had positive perceptions of neighborhood food environment; Agree, those who responded (3), (4), or (5) had negative perceptions of neighborhood food environment; Disagree.

2-5. Statistical analysis

Data were analyzed from the 3,137 adults who provided complete information for all study variables. Respondents who did not provide information regarding education (other/unknown, n = 52) or employment status (other/unknown, n = 80) were not included in the analyses. Interpretation of the results would have been difficult if other/unknown responses were combined with the rest of the data, mainly because there were very few instances where this emerged. Therefore, I excluded these data from the main analyses.

A chi-square test was used to compare various characteristics and vegetable intake levels. Associations between vegetable intake and perceptions of neighborhood food environment were examined using a forced-entry adjusted logistic regression analysis. The dependent variable was vegetable intake, and the independent variables were perceptions of neighborhood food environment. There were no issues of multicollinearity between our variables. Adjusted odds ratios (AOR), and 95% CI were calculated for each variable. Multivariate analyses were adjusted for sex, age, marital status, residence status, employment status, and educational states. All statistical analyses were performed with IBM ® SPSS ® Statistics 21.0 with the p value 0.05 taken as the level of significance.

3. Results

Participant characteristics and food environment perceptions are shown in Table 4. Approximately half of the respondents were women. Individuals who reported sufficient vegetable intake had the following characteristics: 50–59 years old, married, living together, not employed, 3000000–7000000 + yen income, 4-year college/graduate school. The ratio of perceived positive neighborhood food environment to sufficient vegetable intake was higher when compared to individuals reporting insufficient vegetable intake (All items $p < 0.001$).

Table4. Descriptive characteristics of 3137 subjects of vegetable intake and food environment in Japanese adult.

		All				
		Vegetable intake[§]				
		Yes		No		
Variable	Categories	n= n	1453 %	n= n	1684 %	P[†]
Sex						
	Men	631	43.4	949	56.4	<0.001
	Women	822	56.6	735	43.6	
Age						
	30-39 years	458	31.5	614	36.5	0.003
	40-49 years	519	35.7	598	35.5	
	50-59 years	476	32.8	472	28.0	
Marital status						
	Married	981	67.5	907	53.9	<0.001
	Not married[‡]	472	32.5	777	46.1	
Residence status						
	Living together	1282	88.2	1300	77.2	<0.001
	Not living together	171	11.8	384	22.8	
Employment status						
	Employed	1023	70.4	1285	76.3	<0.001
	Not employed	430	29.6	399	23.7	
Household income						
	<3,000,000 yen	345	23.7	639	37.9	<0.001
	3,000,000-7,000,000 yen	630	43.4	663	39.4	
	>7,000,000 yen	478	32.9	382	22.7	
Educational status						
	Junior high/high school	314	21.6	516	30.6	<0.001
	2-years college	411	28.3	455	27.0	
	4-years college/graduate school	728	50.1	713	42.3	
Availability of balanced meals						
Nutritionally balanced foods and menus are available at a nearby restaurant, grocery store, and workplace cafeteria	Agree [¶]	710	48.9	405	24.0	<0.001
	Disagree[¶]	743	51.1	1279	76.0	
Reasonable price for balanced foods						
Nutritionally balanced foods can be purchased at an reasonable price	Agree	934	64.3	601	35.7	<0.001
	Disagree	519	35.7	1083	64.3	
Nutrition labels at restaurants and grocery stores information						
Nutrition labels, such as those containing calorie information, are readily available and useful at nearby restaurants and grocery stores	Agree	630	43.4	409	24.3	<0.001
	Disagree	823	56.6	1275	75.7	
Daily shopping within walking distance						
Daily shopping can be done within walking distance of the home	Agree	857	59.0	761	45.2	<0.001
	Disagree	596	41.0	923	54.8	
Atmosphere to cherish on food culture in my neighbourhood						
My neighbourhood has the atmosphere to cherish on food culture, traditions, and seasonality	Agree	609	41.9	317	18.8	<0.001
	Disagree	844	58.1	1367	81.2	
Atmosphere to feel free to exchange the food with each other in the neighbourhood						
My neighbourhood has the atmosphere to feel free to exchange the food with each other, such as barter of food	Agree	491	33.8	233	13.8	<0.001
	Disagree	962	66.2	1451	86.2	

[†]Chi-square test.

[‡]Not married; single or separated or divorced.

[§]Vegetable intake responses were provided on a scale with four options: (1) Always, (2) Occasionally, (3) Rarely, and (4) Never. Subjects who chose (1) or (2) were considered to have answered positively (1 = Yes), and those who chose (3) or (4) were considered to have answered negatively (0 = No).

[¶]Food environment responses were provided on a scale with five options: (1) Strongly Agree, (2) Agree, (3) Neutral, (4) Disagree, and (5) Strongly Disagree. Subjects who chose (1) or (2) were considered to have answered positively (1 = Agree), and those who chose (3) to (5) were considered to have answered negatively (0 = Disagree).

Results of the logistic regression analysis on the association between perceptions of neighborhood food environment and vegetable intake are shown in Table 5. In the adjusted analysis, perceptions of neighborhood food environment as "Availability of balanced meals" (Middle; AOR = 1.76; 95% CI: 1.29‐2.40, High; AOR = 1.46; 95% CI: 1.01‐2.11) and "Reasonable prices for balanced foods" (Low; AOR = 2.09; 95% CI: 1.47‐2.97, Middle; AOR = 1.63; 95% CI: 1.22‐2.19, High; AOR = 1.85; 95% CI: 1.28‐2.67) predicted sufficient vegetable intake. In terms of social capital, perceptions of the neighborhood food environment as an "Atmosphere of cherishing the food culture in my neighborhood" (Low; AOR = 1.66; 95% CI: 1.11–2.49, High; AOR = 1.82; 95% CI: 1.22–2.72) and an "Atmosphere of feeling free to exchange food with each other in the neighborhood" (Low; AOR = 2.65; 95% CI: 1.72–4.08, Middle; AOR = 1.61; 95% CI: 1.14–2.28) predicted sufficient vegetable intake.

Table5. Association of perception of food environment and vegetable intake in Japanese adults.

		<3,000,000 yen						3,000,000-7,000,000 yen						>7,000,000 yen					
		Vegetable intake[§]						Vegetable intake[§]						Vegetable intake[§]					
		Yes		No		Adjusted[†‡]			Yes		No		Adjusted[†‡]		Yes		No		Adjusted[†‡]	
		n= 345		n= 639					n= 630		n= 663				n= 478		n= 382			
Food environment[¶]		n	%	n	%	AOR	95%CI	P	n	%	n	%	AOR	95%CI	P	n	%	n	%	AOR	95%CI	P
Availability of balanced meals																						
	Agree	136	39.4	119	18.6	1.31	0.87-1.98	0.192	307	48.7	156	23.5	1.76	1.29-2.40	<0.001	267	55.9	130	34.0	1.46	1.01-2.11	0.043
	Disagree	209	60.6	520	81.4		1		323	51.3	507	76.5		1		211	44.1	252	66.0		1	
Reasonable price for balanced foods	Agree	194	56.2	196	30.7	2.09	1.47-2.97	<0.001	401	63.7	241	36.3	1.63	1.22-2.19	0.001	339	70.9	164	42.9	1.85	1.28-2.67	0.001
	Disagree	151	43.8	443	69.3		1		229	36.3	422	63.7		1		139	29.1	218	57.1		1	
Nutrition labels at restaurants and grocery stores information	Agree	114	33.0	120	18.8	0.88	0.58-1.33	0.537	262	41.6	162	24.4	1.03	0.76-1.40	0.864	254	53.1	127	33.2	1.05	0.72-1.54	0.795
	Disagree	231	67.0	519	81.2		1		368	58.4	501	75.6		1		224	46.9	255	66.8		1	
Daily shopping within walking distance	Agree	189	54.8	283	44.3	0.79	0.57-1.10	0.168	354	56.2	289	43.6	0.94	0.72-1.22	0.649	314	65.7	189	49.5	0.95	0.68-1.33	0.764
	Disagree	156	45.2	356	55.7		1		276	43.8	374	56.4		1		164	34.3	193	50.5		1	
Atmosphere to cherish on food culture in my neighbourhood	Agree	135	39.1	99	15.5	1.66	1.11-2.49	0.014	253	40.2	130	19.6	1.38	0.99-1.92	0.056	221	46.2	88	23.0	1.82	1.22-2.72	0.003
	Disagree	210	60.9	540	84.5		1		377	59.8	533	80.4		1		257	53.8	294	77.0		1	
Atmosphere to feel free to exchange the food with each other in the neighbourhood	Agree	115	33.3	67	10.5	2.65	1.72-4.08	<0.001	208	33.0	96	14.5	1.61	1.14-2.28	0.008	168	35.1	70	18.3	1.21	0.78-1.88	0.397
	Disagree	230	66.7	572	89.5		1		422	67.0	567	85.5		1		310	64.9	312	81.7		1	

[†]The independent variable of food environment was adjusted for sex, age, marital status, residence status, employment status, and educational status.

[‡]AOR = Adjust odds ratio; 95% CI = 95% confidence interval.

[§]Vegetable intake Responses were provided on a scale with four options: (1) Always, (2) Occasionally, (3) Rarely, and (4) Never. Subjects who chose (1) or (2) were categorized as positively (1 = Yes), and those who chose (3) or (4) were considered to have answered negatively (0 = No).

[¶]Food environment responses were provided on a scale with five options: (1) Strongly Agree, (2) Agree, (3) Neutral, (4) Disagree, and (5) Strongly Disagree. Subjects who chose (1) or (2) were considered to have answered positively (1 = Agree), and those who chose (3) to (5) were considered to have answered negatively (0 = Disagree).

4. Discussion

4-1. Main Discussion

To our knowledge, this was the first study to examine the association between vegetable intake and perceptions of neighborhood food environments in Japan. These perceptions were in part related to differences in household income, which in turn predicted desirable vegetable intake. Our results shows that the difference by household income is limited, and suggested that is possible to increase vegetable intake across a wide population by promoting perceptions of neighborhood food environments.

High vegetable intake (regardless of income) was related to the perception of "Nutritionally balanced foods can be purchased at a reasonable price." Thus, grocery stores should invest in promotional activities that allow consumers to easily recognize seasonal vegetables through store events and advertisements. Flint [36] reported that perceived availability, affordability, and acceptability of one's neighborhood food environment did not predict fruit and vegetable consumption when targeting low-income individuals. However, Nicole [72, 73] and colleagues implemented a food pricing policy for improving dietary quality for adult women in low- and middle-income brackets. Several studies worldwide have focused their assessments on lower-income individuals [37], with no prior reports examining a wide range of income groups. Furthermore, mechanisms underlying food distribution and vegetable acquisition are different in Japan. A Japanese public opinion survey [74] revealed that approximately 64% of respondents said that "price" was an important element when purchasing perishables. Vegetables are highly influenced by seasonal and weather elements, which influence price fluctuations. Consumers may be affected by temporary price hikes. However, in Japan, there are environments where vegetables can be obtained at relatively uniform prices. Across the four seasons in Japan, specific vegetables can be reasonably obtained. Thus, promoting the benefits and usefulness of seasonal vegetables will be beneficial for the whole country. The present study also focused on vegetables, not fruits, which are unique to Japanese food guides. Taking these differences into consideration, the present results could be particularly specialized to a Japanese context.

Regardless of SES, by improving perceptions of the "social capital about food," which include "Atmosphere of cherishing the food culture in my neighborhood" and the "Atmosphere of feeling free to exchange food with each other in the neighborhood," there is a

possibility of predicting the sufficiency of vegetable intake. Among the lowest- income bracket in Japan, there is an average vegetable intake of about 70 g (1 SV) less than highest income, with low SES groups experiencing a higher risk for lifestyle-related diseases [21]. Motohashi [35] reported that vegetable intake is lower among individuals who perceive an environment of negative community social capital. Social capital [75] is defined as a relationship of mutual trust (social network) between individuals. Health Japan 21 (the second term) states that reinforcement of social capital is important for health promotion among the socioeconomically disadvantaged. For example, there are two health promotion activities that could be implemented based on region and organization. First, supporters of municipalities and organizations could provide information regarding the local food culture and traditions, as well as outline the importance of sharing foods in the community. This could be accomplished through public service announcements and advertisements spearheaded by local governments. Second, it may be good for local governments, grocery stores, and restaurants to host events where consumers can experience positive social capital in regards to the food culture. Increasing a focus on "social capital" could lead not only to advocating for vegetable intake but also holistic community health promotion.

The association between desirable vegetable intake and perceptions of the neighborhood food environment, as it pertains to the availability of balanced meals (such as nearby restaurants, grocery stores, and workplace cafeterias), was only observed among the middle and highest income brackets. Maintenance of nutritionally balanced foods and menus within organizations, local grocery stores, and restaurants is currently underway in Japan [20]. However, the present results indicate that individuals within the lower income brackets may not benefit from this association. Thus, it is necessary to devise interventions where these individuals become vigilant toward checking nutritional information on menus and labels. Each municipality in Japan is implementing a system that recognizes a "mark," which highlights dishes that use several vegetables and stores that offer "vegetable supporter" dishes. Additionally, I created an enlightenment tool, referred to as the "Everyday plus one dish of vegetables"[76], as a national strategy. This initiative has been implemented at grocery stores since 2016. In order to plan a health promotion strategy that focuses on lower income individuals, it is necessary to make use of these tools and actively promote food awareness across a variety of organizational levels.

4-2. Limitations and implications

The present study included a few notable limitations. First, I could not investigate any objective indices (e.g., geographic information system) of the food environment. Second, we were unable to consider other factors that may influence food purchases, including the types of stores patronized, food prices, or other aspects of the food-purchasing environment (e.g., grocer displays [70]). Third, despite our rather large sample size, I cannot guarantee that our sample is fully representative of the general Japanese population (i.e., I only sampled individuals with access to the Internet). Participants were randomly selected based on Japanese population data according to demographics, which was an advantageous aspect of the present study. Moreover, this strategy helped us avoid issues related to regional characteristics. Thus, the key advantage of this Internet-based survey was that it was possible to utilize a variety of sampling parameters. However, Internet-based survey respondents may be more likely to have certain characteristics, including being younger, have a higher level of education, and a higher income [66, 67].

The Japanese government has recently recommended an approach that includes distinct health promotion interventions based on specific income levels [20]. However, investigating SES is a delicate issue for low-income households. The possibility of implementing a health promotion strategy within segmentation of income groups is quite challenging in reality. Furthermore, recent studies have shown that two-thirds of Japanese adults do not attain recommended vegetable consumption level (350 g/day). Therefore, regardless of SES, promotion of vegetable intake is an important dietary issue. Our results did not differ greatly based on SES level in terms of the relationship between desirable vegetable intake behavior and food environment recognition. Therefore, food environment perception and vegetable intake promotion efforts should target all income levels. Therefore, our next task is to investigate whether I am effective at improving vegetable intake by altering food environment perceptions at the population level.

Ⅶ. Study 2: A randomized-controlled trial focusing on socio-economic status for promoting vegetable intake among adults using a web-based nutrition intervention program: Study protocol

1. Background

Appropriate vegetable intake appears to be effective for cancer prevention [14, 15, 25] and is associated with reduced risks of cardiovascular disease [15, 17, 18], obesity [16], and other lifestyle-related diseases. Health policy initiatives are promoting vegetable intake across all segments of the population worldwide. However, in practice, it has been widely reported that vegetable intake remains low among social disadvantaged groups in terms of household income and other indicators of SES [5, 6].

As part of efforts to promote vegetable intake among adults, several nutrition education programs that have incorporated aspects of behavioral science theory have proven effective [38-40]. Web-based intervention programs are of particular note, and several have been developed and verified outside of Japan [45-52, 54, 78]. Neuenchwander et al. [48] compared the effects of face-to-face nutrition education with a web-based education, and found that changes in vegetable intake prompted by the web-based programs were comparable with those achieved through the face-to-face programs. Additionally, Bensley et al. [47] reported that provision of information through bulletins board increased vegetable intake by 0.2 serving while a web-based intervention increased intake by 0.6 serving.

Despite these promising findings, only the reports by Buller [54] and Ball [45] considered SES in relation to web-based nutrition education programs, indicating an extreme paucity of research in this area. Buller et al. demonstrated that it is possible to implement web-based nutrition education programs even in agricultural communities lacking an adequate web infrastructure. Of course, a remaining challenge is that their findings are limited to agricultural communities. There are no studies comparing the effects of different SES.

In Japan, the recommended daily amount of vegetables is 350 g, from the perspective of preventing lifestyle-related diseases [20]. Nevertheless, approximately two-thirds of adults do not meet this recommendation [21] – in particular, the average daily vegetable intake for adults is around 70 g below the recommended amount. The average daily intake among lower-income social groups is a further 70 g lower than that among higher-income groups. Ournationwide survey of adults on the actual situation regarding the

relationship between socio-economic status and dietary habits showed that, lower-income groups are less likely to have a habit of eating 5 servings of vegetables daily than are higher-income groups [23]. However, even among higher-income groups, the proportion of individuals who customarily consume 5 servings of vegetables daily is extremely small, at approximately 10% of the population [77]. Thus, support for the increased intake of appropriate vegetables should be implemented using a population-based approach that targets not only lower-income groups, but also the entire adult population. I hypothesize that achieving an approximately 70 g (1 serving) increase in vegetable intake might help lower-income groups to catch up while simultaneously contributing to the partial resolution of the deficient vegetable intake amongst Japan's adult population.

In Japan, Ministry of Internal Affairs and Communications report on Internet usage by Japanese citizens [78] shows that, today, the proportion of Internet users among all Japanese citizens aged 30–59 is 90% or more. Furthermore, the proportion of lower-income individuals (i.e., who are earning less than 2 million JPY per annum; approx. 15,800 GBP) is 61%, and rising annually. A relatively high proportion of respondents to this report indicated that they use the Internet to search for information about health and medicine, ranging from 73% among 30-year-olds to 80% among 59-year-olds. The proportion of respondents who reported using the Internet at least once a week was as high as 91%. Thus, as a form of information and communications technology (ICT), the Internet is a powerful health education tool for which future expansion can be anticipated in fields of health promotion, especially nutrition [79]. Web-based nutrition education programs by their nature rely on ICT and the Internet in particular [80]. However, in the context of web-based support for increased vegetable intake, there are almost no reports, even at the worldwide level, verifying the effects of these programs according to income level.

In this paper, I describe the methods and protocol of a RCT that seeks to verify the effectiveness of a web-based nutrition education program of promoting vegetable intake among adults and that is based on behavioral science theory. The main objective of the RCT is to develop and verify the effects of a 5-week program of promoting vegetable intake. A secondary objective is to determine how the effects of this web-based nutrition education program differ according to SES.

2. Methods

2-1. Study design

This study describes a two-armed, matched-design, web-based RCT. The nutrition education program that I have developed as part of a health promotion project (Figure 4). The intervention period is five weeks. The RCT is designed in line with the CONSORT statement for randomized trials of non-pharmacologic treatment [81]. Participants were assessed at three points in time: at baseline (T1), at post intervention (5 weeks later; T2), and at a follow-up at three months (T3). The participants were randomly assigned to one of two conditions: the intervention group and the waiting list group (i.e., the control group). Details of the method followed the SPRIT statement [82].

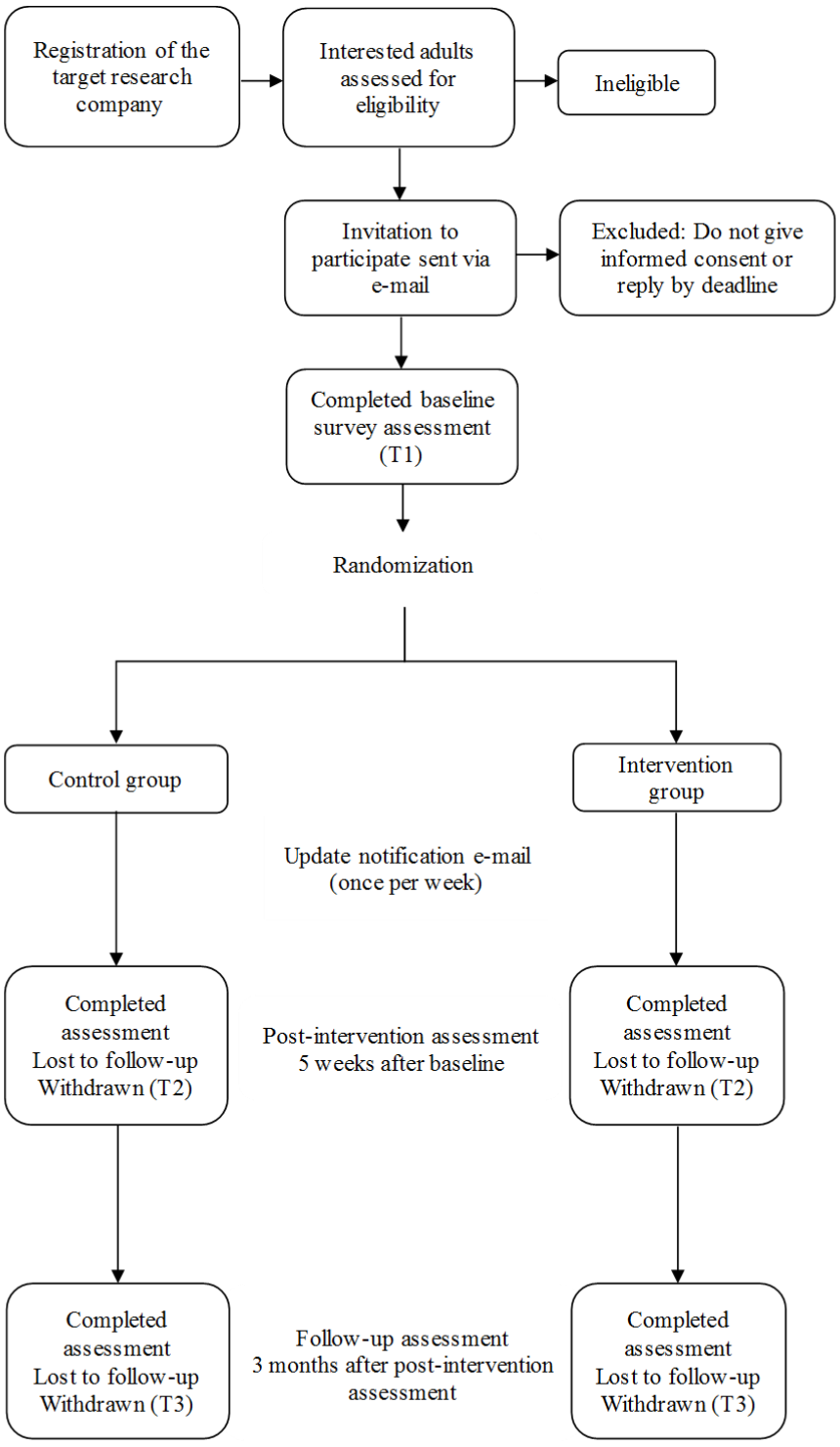

Figure 4. Flow chart showing participant recruitment, randomization, and evaluation of the Diet and Exercise Practices Project study.

2-2. Ethics approval

The RCT was conducted according to guidelines laid out in the Declaration of Helsinki for procedures involving human subjects, and has been approved by the Ethics Review Committee on Research with Human Subjects of Waseda University, Japan (2015-167). The respondent's privacy and personal information are fully protected due to agreement between the registration monitor and the social research company used to recruit participants. All e-mails were sent to participants by the research service company, and I have received a database containing only non-specific, anonymized data.

2-3. Recruitment source and procedure

A web-based intervention survey was conducted by a Japanese online research service company that contains data, including sociodemographic attributes, for approximately 111,000 adults aged 30–59 years. Participants were randomly selected based on Japanese population statistics for the present study. I targeted adults because of the necessity of health promotion, healthy eating, and reduction in health disparities for this age group [23]. The following inclusion criteria are considered: (1) men and women aged 30–59 years old; (2) able to understand Japanese; (3) can access the Internet at home, work, or a public place; (4) agree to access the study website during the 5-week intervention period; (5) will participate in all three assessment points during the four-month study period. The exclusion criterion is having an household income of 10 million yen or more (meaning that 88.4% of the total population is having an household income of 10 million yen less) [83]. The study procedure from enrolment to follow up is depicted in Figure 4.

The research company that I used in the present study periodically analyses and updates its registrant database. A notable characteristic of this company is that, to prevent bias among survey respondents, the firm requests the participation of the minimum number of respondents after taking response rate into consideration. Moreover, once every six months, the firm updates its monitoring information and conducts checks to safeguard against double registration or non-existent IP addresses. Registrants had been enrolled with the survey company by an open recruitment process.

Study participants were recruited using the following procedure. Of the approximately 111,100 registered monitors (as of September 2015), participants randomly to match the sex, age [83], and household income [60] distributions of Japan. Only study participants received an

e-mail containing the website URL and password. Participate in the study were randomly assigned it to two groups in the order that received an answer to the intervention or control groups by the online research service company. The web-based nutrition educational program is available in HTML format. Respondents who completed the questionnaire and clicked the 'send' button at the end of the online informed consent form were considered to have consented to survey participation (n = 1,500). The research service company offered reward points valued at 40 JPY (in October 2015, one USD was equivalent to approximately 120 JPY) at T1. Of these, individuals who were allocated to the intervention group were offered reward points valued at 300 JPY after completion of the intervention (T2). Respondents from the control group were offered reward points valued at 40 JPY at T2. The participants were again offered reward points valued at 40 JPY for completing the assessment at three months after the completion intervention (T3; i.e. four months after the completion of the baseline survey [T1]).

2-4. Setting

Regarding the setting, at baseline (T1), individuals consenting to participate in the study were randomly assigned it to two groups in the order that received an answer to the intervention or control groups by the online research service company. The researchers were not involved in this allocation in any way. All participants received a notification e-mail informing them of their allocated groups. The groups were listed as P Group (intervention group) and Q Group (control group) to prevent participants from knowing which group they were assigned to. This study is signal a type of single blinding. Because it is not the intervention of face to face, there is no contact during the intervention period.

2-5. Intervention group

Participants assigned to the intervention group received an e-mail containing the dates of program updates, the website URL of the intervention program, a password for browsing the website, and the following information.

The program updates were sent on Monday morning of each week during the intervention period. Participants received a total of five e-mails on the nutrition education program over the five weeks of the intervention period. On the first occasion, participants received an e-mail containing (1) instructions on how to access the website (i.e. the URL and password), (2) an overview of the program and how it would proceed, and (3) the program

contents for the first week. The e-mails sent in the subsequent weeks, in addition to item (1-3), included a review of the contents of the previous step. The program website was made freely accessible only for the duration of the intervention period, and after which it was closed. Participants' passwords were effective for the duration of the study. If a participant forgot his or her password, it could be retrieved by contacting a research officer. After completion of the five-week intervention, participants received an e-mailed request to participate in the post-intervention survey (T2). Finally, participants received another e-mail request to participate in a follow-up survey three months after completing the intervention (T3).

2-6. Control group

The control group surveys took place over the same period as intervention group surveys. Control group participants received an advance notification e-mail after the baseline from the survey company that another survey would take place five weeks later. After a five-week-long silence, participants received an e-mail request to take part in the post-intervention survey (T2). Subsequently, participants received an e-mail request to participate in a follow-up survey three months later (T3).

2-7. Intervention program

An interactive webpage called the 'Diet and Exercise Practices Project (http://healthpromotionqol.com/)' is designed to improve vegetable intake of visitors to help decrease the likelihood of lifestyle-related diseases (Figure 5). It is a free website that provides information, a monitoring sheet, and advice about healthy diets, increasing vegetable intake, and preventing lifestyle-related diseases. I hypothesize that achieving an approximately 70 g (1 serving) increase in vegetable intake might help lower-income groups to catch up while simultaneously contributing to the partial resolution of the deficient vegetable intake amongst Japan's adult population. Therefore, the action goals of intervention is a vegetable dish to eat 5 servings, or was a plus 1 serving (approximately 70g) per day. The program is divided into five steps that align with the stages of behavior change. Table 1 shows the framework of the program. To be updated every week, but watch the past step not proceed in the previous step. It was created to advance the based on behavioral science theory. To avoid contamination during the intervention period, access to the webpage was password-restricted so that only study participants could visit it.

In order to achieve this action goals were designed following the intervention program (Table 6). To encourage behavioral changes, the program contents are prepared using behavioral theories and techniques tailored to the individual stages of behavioral change. In the first step, I employ the health belief model to encourage a shift from the pre-contemplative to the contemplative phase; in the second and third steps, social cognitive theory is used to encourage transition to the preparatory phase; in the fourth step, social cognitive theory and strengthening social support are used to promote progression to the execution phase; finally, in the fifth step, strengthening social capital and social support are used to promote the shift to the maintenance phase. All of the steps is composed of four items, as introducing "Today's point (two weeks later, including the last time of review)", information and skills necessary to behavior modification as practical content "Do you know?" and "Easy in devising" are on 2 page, as summary "Let's try it !(to support behavior change by using a work sheet) "

2-8. Web design

The website design was settled on through consultations with registered dieticians, health movement educator, and public health experts. Regarding the size of the online text, the amount of information, and the configuration of the website, we obtained the advice of web design professionals. Figures 5 and 6 show a snapshot on program of the website, while the website structure is shown in Figure 7.

Figure 5. A snapshot of the website.

Figure 6. A snapshot on program page of the website..

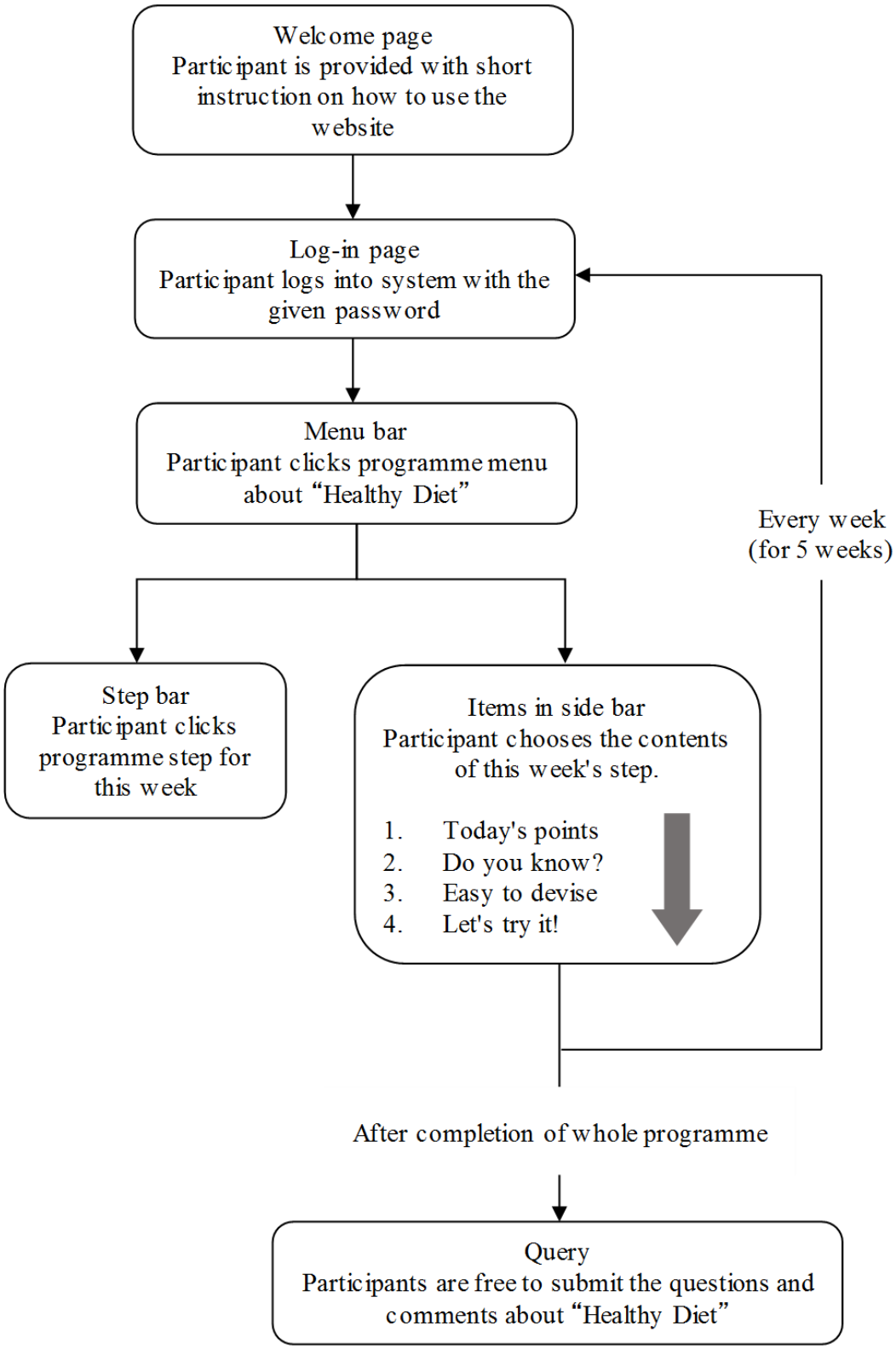

Figure 7. Website structure.

Table6. Five steps and accompanying components of the nutrition education intervention

Step	Stages of change and message	No	Items	Topics	Practice points (e.g., worksheets)	Behavioral science theory	Behavioral modification technique	Health literacy	Processes of change
1	Precontemplation →Contemplation (Encourage interest in vegetables)	1	Today's points	Eating a lot of vegetables is good for our health		Health belief model	Perceived susceptibility, perceived severity	Seeking information from various sources, Extracting relevant information	Dramatic relief, raising awareness
		2	Do you know?	It is recommended that we consume 350g of vegetables per day	Points: 350 g of vegetables = 5 servings	Cognitive behavior therapy	Cognitive restructuring	Seeking information from various sources, Considering the credibility of the information	Dramatic relief, raising awareness
		3	Easy to devise	Self-check! Counting the number of vegetable dishes	Self-check: How many vegetable dishes (servings) do you eat per day?	Social cognitive theory, theory of planned behavior	Self-monitoring	Considering the credibility of the information	Raising awareness
		4	Let's try it!	Live a healthy life by eating vegetables daily	Worksheet: record the number of vegetable dishes (servings) that you ate daily.	Social cognitive theory, theory of planned behavior	Subjective norm, self-monitoring	Considering the credibility of the information, Making decisions based on the information	Raising awareness

Table6. Five steps and accompanying components of the nutrition education intervention (Continued)

Step	Stages of change and message	No	Items	Topics	Practice points (e.g., worksheets)	Behavioral science theory	Behavioral modification technique	Health literacy	Processes of change
2	Contemplation →Preparation (Try to increase number of vegetable dishes by one (+1))	1	Today's points	You decide your one dish (+1)	Points: Let's choose the "+1" with the confidence so we can practice it at home and	Social cognitive theory, theory of planned behavior	Contingency management	Extracting relevant information	Self-reevaluation
		2	Do you know?	At home: Behind the convenience Easy recipes for your one dish (+ 1)		Social cognitive theory, theory of planned behavior	Role playing	Seeking information from various sources, Extracting relevant information	Raising awareness, counterconditioning
		3	Easy to devise	Eating out: How to choose simple dishes depending on your one dish (+1)		Social cognitive theory, theory of planned behavior	Role playing	Seeking information from various sources, Extracting relevant information	Raising awareness, counterconditioning
		4	Let's try it!	Let's do so! Eat your one dish (+1) from today onwards	Worksheets: I will try my "+1" for today's meal!	Stimulus-response theory, social cognitive theory	Stimulus control, goal setting, self-monitoring	Extracting relevant information, Making decisions based on the information	Self-liberation

Table6. Five steps and accompanying components of the nutrition education intervention (Continued)

Step	Stages of change and message	No	Items	Topics	Practice points (e.g., worksheets)	Behavioral science theory	Behavioral modification technique	Health literacy	Processes of change
3	Contemplation →Preparation (Meals can be opportunities to evaluate one's dietary balance)	1	Today's points	Eat a proper meal based on your confidence in the future of your health	Points: Let's check whether a meal contains everything (i.e., a staple food, a	Social cognitive theory, theory of planned behavior	Contingency management, commitment	Extracting relevant information	Self-reevaluation
		2	Do you know?	At home: Tonight's dinner is now OK		Social cognitive theory, theory of planned behavior	Role playing	Seeking information from various sources, Extracting relevant information, Making decisions based on the information	Raising awareness, counterconditioning
		3	Easy to devise	Eating out: balance achieved by combining foods is OK	Try: Let's choose meal that contains a staple food, main dish, and side dish when eating out or at a convenience store.	Social cognitive theory, theory of planned behavior	Role playing	Seeking information from various sources, Extracting relevant information, Making decisions based on the information	Raising awareness, counterconditioning
		4	Let's try it!	Challenging your to balance your meal	Work sheets: I practice the goal that this myself decided!	Social cognitive theory, theory of planned behavior	Role playing, commitment, self-monitoring, behavior analysis	Extracting relevant information, Understanding and communicating the information, Making decisions based on the information	Self-liberation

Table6. Five steps and accompanying components of the nutrition education intervention (Continued)

Step	Stages of change and message	No	Items	Topics	Practice points (e.g., worksheets)	Behavioral science theory	Behavioral modification technique	Health literacy	Processes of change
4	Preparation →Action (Precautions for a healthy diet)	1	Today's points	What do you do if you cannot eat?		Social cognitive theory, theory of planned behavior	Contingency management	Seeking information from various sources	Environmental reevaluation
		2	Do you know?	Practical examples: recommended measures		Stimulus-response theory	Stimulus control, counterconditioning	Extracting relevant information, Considering the credibility of the information, Making decisions based on the information	Stimulus control, counterconditioning
		3	Easy to devise	Characteristics of those who are eating plenty of vegetables	Self-check: What precautions do you take? Check each item that applies!	Stimulus-response theory	Counterconditioning, modeling, self-monitoring, behavior analysis	Seeking information from various sources, Considering the credibility of the information, Extracting relevant information	Stimulus control, counterconditioning
		4	Let's try it!	Devise a goal: Let's make precautions for when something does not work	Try: In case eating a "+1" does not go well, let's decide on a precaution beforehand.	Stimulus-response theory	Commitment, stimulus control	Extracting relevant information, Considering the credibility of the information, Making decisions based on the information	Stimulus control, self-liberation

Table6. Five steps and accompanying components of the nutrition education intervention (Continued)

Step	Stages of change and message	No	Items	Topics	Practice points (e.g., worksheets)	Behavioral science theory	Behavioral modification technique	Health literacy	Processes of change
5	Action →Maintenance (Healthy community helps us)	1	Today's points	Everyone's goal is to improve their health		Social cognitive theory, theory of planned behavior, social network, social support	Contingency management, self-monitoring	Extracting relevant information, Considering the credibility of the information, Making decisions based on the information	Helping relationships, social liberation
		2	Do you know?	Eat a delicious meal together with family and friends!	Self-check: What kind of topic do you talk about with family and friends?	Social cognitive theory, theory of planned behavior	Subjective norms, self-monitoring	Extracting relevant information, Understanding and communicating the information, Making decisions based on the information	Helping relationships, social liberation
		3	Easy to devise	Investigate safe diets in the community	Try: Let's look for a shop that supports health promotion in your community!	Social cognitive theory, theory of planned behavior	Subjective norms	Seeking information from various sources, Extracting relevant information	Helping relationships, social liberation
		4	Let's try it!	Let's be healthy by eating vegetables! Spend a day having a fun diet	Try: Let's review a past topic! Try: Let's settle on a "+1" that you can begin introducing to family and friends! Free description: Questions and free comments	Social cognitive theory, theory of planned behavior	Commitment, self-monitoring, contingency management	Extracting relevant information, Considering the credibility of the information, Understanding and communicating the information, Making decisions based on the information	Social liberation

2-9. Assessment

The primary outcome variable was assessed using a self-administered questionnaire in Japanese. Regarding the assessment, at baseline (T1), primary outcomes, transtheoretical model [58], self-efficacy [84], dietary knowledge [85], perceptions of neighborhood food environments within secondary outcomes, and all other measurements. After completion of the five-week intervention, participants received an e-mailed request to participate in the post-intervention survey (T2). At post-intervention survey (T2), I assessed the all primary outcomes, all secondary outcomes, and all other measurements excluding the subjective economic status. I evaluated about the participants' satisfaction of process evaluation as after intervention. Finally, participants received another e-mail request to participate in a follow-up survey three months after completing the intervention (T3). At follow-up survey (T3), I assessed the all primary outcomes, all secondary outcomes, and all other measurements excluding the subjective economic status.

As Health Japan 21 (second term), it is necessary to evaluate the intervention that applies to the improvement of diet-related quality of life. Interventions that focus on dietary lifestyle require evaluation of diet-related quality of life as primary outcomes. Two of the subscales of the Subjective Diet-Related quality of life scale includes dietary satisfaction and fun of meals. As primary outcomes, I considered Subjective Diet-Related quality of life, which comprised an assessment of the final dieting goal (2 items) [86], and self-rated health, which has been reported to be associated with both socio-economic status and mortality [12, 87].

The secondary outcomes were eating behaviors, which was considered an index of behavioral change and is often held up as the goal of nutrition education. Three eating behaviors (per week) were considered: mealtime balance, or eating 'balanced meals comprising a staple food, a main dish, and a side dish' [57], 'eating dark green vegetables', and 'eating full servings of vegetables (5 small dishes or approx. 350 g per diem)' [63]. The mealtime balance behavior has been shown to facilitate nutrient intake and improve nutritional status [88–90]. To explain the staple foods, main dishes, side dishes, and vegetable servings, I posted sample photographs for reference in terms of size and amount, and stipulated that respondents should always check these photographs before responding. Because daily eating behaviors (2 items) were checked using these photographs depicting single (70 g) servings of vegetables, participants were also asked to answer how many vegetable servings they consumed per diem. This item reflects the fact that, as demonstrated by Ozawa et al. [62], the behavioral goal of '5 or 6 small [vegetable]

dishes a day' can potentially serve as an easily grasped indicator of consuming 350 g per diem. Additionally, the amount of vegetables eaten each day (in g) was also self-reported.

As our intention was to evaluate not only outcomes, but also the processes leading to behavioral change, I also employed secondary items assessing diet. I used a measure based on the TTM [58] (containing 3 items) to evaluate the intermediate factors relating to secondary-outcome eating behaviors, and a measure of self-efficacy [84] (also containing 3 items) as an evaluation of preparatory factors. I also used two items [85] to assess dietary knowledge concerning secondary-outcome eating behaviors. Perceptions of neighborhood food environments relating to eating behavior was assessed with 10 items [34, 91].

I also measured health literacy [92], which is defined as the knowledge, desire, and skills for acquiring, comprehending, evaluating, and making use of health information, using a scale with good validity for the Japanese population. In the context of our previous research, the relationship of health literacy with vegetable intake behavior was shown to be unaffected by socio-economic status, whereas promotion of vegetable intake behavior has the potential to improve health literacy [93]. In addition, I measured subjective economic status [95], household income [60], educational attainment [23, 77, 93], and other attributes (namely sex, age, marital status, living arrangements, and employment status).

2-10. Process evaluation

Adherence to the intervention was assessed by the number of log-ins and duration spent in the website. Furthermore, the participants' satisfaction with the intervention was assessed by using a self-administered questionnaire at post-intervention. With reference to previous studies on program development [43, 95], I also included an evaluation (5 items) of the nutrition education program itself. The items were as follows: (1) was the content of the program fun? (2) was the content of the program easy to understand? (3) after participating, did you become aware of any problems in your own diet? (4) did you feel the program was helpful as a health management material? and (5) as a health management material, did it make you want to participate again another time?

2-11. Sample size

The sample size was calculated using G*Power [96]. I set an effect size of 0.5, an α of 0.05, and a power of 0.95. With the expectation that two-thirds of participants would drop

out, the size of the intervention group was set at 900 participants, while that of the control group was set at 600 participants with the expectation that a half of participants would drop out. Furthermore, I aimed to divide the intervention and control groups further according to income (low and high).

2-12. Statistical analysis

All statistical analyses will be performed with IBM SPSS Statistics 21.0. For continuous variables, independent t-tests will be used to determine inter-group differences and Man–Whitney U-tests for intra-group comparison, while the χ^2 or an equivalent test is to be used to determine the associations between categorical variables. Because this is a prospective RCT involving repeated measures, repeated measures analyses of variance will be applied to determine significant differences within the study groups. I also considered the possible effect of time on groups. The evaluation of the intervention is based on an intention-to-treat analysis. A p-value of 0.05 has been set as the level of significance.

3. Discussion

3-1. Main Discussion

This study describes an RCT of a web-based nutrition education program. Promoting vegetable intake is an important challenge for health promotion during adulthood, regardless of SES. Japanese adults of all household income levels consume less than approximately two-thirds of the recommended daily amount (i.e. 350 g or 5 servings per day). Support for the increased intake of appropriate vegetables seems best implemented using a population-based approach, as this issue is necessary for not only lower-income groups, but also the entire adult population. Web-based nutrition education programs are communication tools that use ICT, in particular the Internet. In other words, it is a health education tool for which future expansion can be anticipated in fields of health promotion. If I could show that such web-based nutrition education programs are beneficial for improving vegetable intake, our population-based approach would enable lower-income groups to catch up in terms of averaged daily intake of vegetables while also contributing to the resolution of the overall deficiency in vegetable intake in Japan’s overall adult population. So far as I know, this is the first report regarding a web-based nutrition education program developed with a focus on SES.

3-2. Strengths, limitations and implications

This study has three main strengths. First, this is an RCT using high-quality research methods. Because the RCT participants were assigned randomly, there is very little allocation bias. Additionally, randomization took place after acquiring consent to participate, which means that the intervention group was not populated only with participants actively interested in the research topic. This helps in avoiding over-estimation of the effects of the nutrition education program in the intervention group. Second, this is nutrition education program was web-based, thus making it highly accessible. Furthermore, the study was carried out by a social research company with a wealth of experience in implementing academic research surveys. These points ensured high feasibility while minimizing the burden of securing an adequate sample size to increase statistical power. In addition, participants could be extracted to match the distribution of sex and age in the Basic Resident Register and household income in the Comprehensive Survey of Living Conditions. For this reason, possible confounding effects could for the most part be eliminated at the stage of allocation. Third, the program affords numerous advantages for both participants and supporters. Participants can take part when they are free to do so (e.g. time, place, and scheduling). As this means that they can take part even if they are located far away from the researchers, it would be highly convenient for participants [79]. The program also offers supporters the opportunity to provide a unified nutrition education program that is not reliant on the number of participants and to provide support without being subject to spatial or geographical restrictions. While it is true that the initial cost is somewhat considerable, its operational costs are low. The economic burden on supporters is thus small. Furthermore, passwords can be set for browsing the nutrition education program, which can prevent communication between groups that could impact the quality of research.

The RCT in this study is original in the following two regards. (1) It can verify the intervention effect for an adequate sample size, and (2) it can verify differences in the effect of a nutrition education program by income. With this study, it will also be possible to verify the possible catch-up effect in relation to undesirable vegetable intake behavior associated with low household income. Some reports have suggested that traditional classroom-based nutrition interventions might widen this disparity [5]. In contrast, with our study, it may be possible to show that a web-based nutrition education program would inhibit the widening of this disparity.

Conversely, this study also has its limitations. It is possible that the results of the study will reflect the characteristics of individuals registered with the research company (e.g., tending

to be young, high-earning, and highly educated [66–68]). To minimize this potential limitation, I have made sure to match participants with demographic distributions in terms of sex, age, and household income. In addition, I requested research cooperation from individuals whose household income data – which was our objective – had been recorded in advance. This helps to restrict attribute bias as well as negative response rates for delicate questions pertaining to household income and other matters. Second, during participant recruitment, I excluded individuals reporting household incomes of 10 million JPY or more. This means that the results do not target the entire population. Accordingly, care must be taken when drawing general conclusions. However, a limit of less than 10 million JPY still applies to 88.4% of the Japanese population. Finally, participants did not have contact with one another (either in person or through indirect communication) for the period of the intervention. For this reason, it is possible that rates of adherence to nutrition education programs will be lower than they would with enforced participation.

The promotion of vegetable intake behavior is an important challenge for health promotion during adulthood, regardless of SES. Healthy Japan 21 (second term)' policy initiative [20] is promoting the use of ICT as a health promotion strategy for the future. Because ICT frees individuals from the limitations of time or place, it may be a tool that encompasses individuals in lower socio-economic strata who have little time to spare. If I can show that web-based nutrition education programs have a positive effect, our study would represent the outcome of a population approach as a health promotion strategy.

Ⅷ. Study 3: Reduction in vegetable intake disparities with a web-based nutrition education intervention among lower-income adults in Japan: randomized-controlled trial

1. Background

Reducing health disparities is important for public health promotion [2]. Disparities in food intake are known to occur among socioeconomically disadvantaged people [5-7]. Appropriate vegetable intake prevents cancer [25] and obesity [16], and reduces the risk of cardiovascular disease [15, 17, 18] and other lifestyle-related diseases. Despite this, individuals with low SES tend to have low vegetable intake [21]. Thus, promoting vegetable intake in low-SES individuals to reduce health disparities is important globally.

Japan has one of the highest levels of longevity in the world. However, recently, health disparities have been recognized as a social problem [11, 13]. Health Japan 21 [20] recommends a vegetable intake of 350 g (5 servings) per day for adults in order to reduce health disparities related to lifestyle-related diseases. However, low-income people tend to consume few vegetables [21] (in the lowest income bracket: men 254 g per day, women 282 g per day). In cross-sectional study of Japanese adults, a low percentage of individuals with lower income (less than 3,000,000 JPY) ate 5 servings (approximately 350 g) of vegetables daily: men 5.5%, women 10.4% [77]. Currently, practical strategies for reducing vegetable intake disparities are lacking, and are therefore urgently needed.

A systematic review revealed that research has utilized multiple health behavior theories in attempting to increase vegetable intake, such as stages of change [58], social cognitive theory [97], the theory of planned behavior [98], and technology-based behavior change models [39, 40]. Henry et al. [31] suggested that possibility to increased vegetable intake in low-income women using a nutrition education intervention focusing on improving self-efficacy (PBC) [84]. Thus, the gap in vegetable intake between low- and middle-income individuals might be reduced through a multi-component nutrition education program that focuses on self-efficacy. It is therefore necessary to evaluate the nutrition education program developed in terms of whether it produces the intended outcome in evaluating nutrition education based on multi-component nutrition education program, not only outcome evaluation but also process evaluation, such as perceived behavioral control.

There are some concerns on applying web-based interventions to socioeconomically disadvantaged populations, as they might have access only to poorer quality internet environments. Nevertheless, web-based interventions are generally easier to access, are low cost, and tend to be comfortable for most users. They similarly have advantages in being able to provide standardized information regardless of place or population size. These interventions have been drawing attention in recent years, with many studies confirming their efficacy in health promotion in adults [29, 30, 49-51]. For instance, web-based interventions were able to increase vegetable intake in low-SES adults in rural America [48, 54]. However, these studies did not examine reductions in vegetable intake disparities, because they focused only on individuals with low SES.

Our study was designed to investigate reductions in vegetable intake disparities between low and middle-income adults. I developed a web-based nutrition education program that incorporates multiple health behavior theories in order to promote vegetable intake [99]. The aim was to investigate the effects of this program on the vegetable intake and patterns of change in vegetable intake of low- and middle-income adults.

2. Methods

2-1. Trial design and ethics

I previously reported the details of the nutrition education program in a study protocol [99]. This study was a matched-design, RCT. Participants were assessed by self-report at three time points: baseline (T1), post-intervention (T2), and follow-up at 3 months (T3). The study period ranged from October 2015 to March 2016. I obtained baseline (T1) data in October, and post-intervention (T2) data in December; the follow-up period was March 2016 (T3; i.e., three months from December). All intervention group participants completed the intervention in the same 5-week period. All control group participants completed the survey at all three time points, but did not undergo the intervention program. The RCT was approved by the Ethics Review Committee on Research with Human Subjects of Waseda University, Japan (2015-167), and Current Controlled Trials (UMIN-ICDR UMIN000019376).

2-2. Participants and recruitment

Figure 8 shows the study participant recruitment and flow. A Japanese online research service company containing data from approximately 111,000 people (as of

September 2015) conducted the survey at all 3 time points (T1–T3). The research service company randomly selected 8,564 people adults aged 30–59 years to match the gender and age [60] distributions of Japan at baseline (T1). I targeted adults aged 30–59 because I felt that both the promotion of healthy eating and reduction in health disparities were particularly important in this group. In the past, I carried out a cross-sectional study on the relationship between socioeconomic status and dietary habits in this age group [23, 78, 93, 99]. If participants met any of the exclusion criteria, they were not sent an email. Therefore, it is unknown why participants were excluded. The exclusion criterion were an annual income of more than 10,000,000 JPY (in October 2015, one USD was equivalent to approximately 120 JPY; 88.4% of the total population has an income of less than 10,000,000 JPY). Recruitment was terminated when the number of participants who agreed to participate reached 1,500 (T1). The research service company randomly divided participants into intervention and control groups, and collected data via computer. The authors were blinded to the randomization. Participants received a detailed explanation of the research because of ethical considerations, and were informed that they had been randomly assigned to their group. However, since participants did not obtain any information about the other participants, we believe that there was no contamination bias. The details of the incentives of this research are described in the study protocol [99].

The sample size was calculated using an effect size of .5, an α of .05, and power of .95 [99]. Among participants with incomes of less than 3,000,000 JPY and those with incomes of 3,000,000–10,000,000 JPY, allocation was as follows: n = 450 (intervention) and n = 300 (control). Most adults in Japan have incomes of 2,000,000–3,000,000 JPY, accounting for one third of the Japanese population [84]. Our previous survey showed that percentage of eating 350 g (5 servings) of vegetables daily among individuals earning less than 3,000,000 JPY was obviously less (men 5.5%, women 10.4%) compared with those earning over 3,000,000 JPY [77]. Therefore, 3,000,000 JPY was used as the relative cutoff point. Because most of the total population earn less than 10,000,000 JPY, this upper limit was set in consideration of ceiling effects [83]. The size of the control group was set at 600 participants; the expected dropout rate was about 50% according to the research service company during the survey period. The size of the intervention group was set at 900 participants, with an expected dropout rate of two-thirds. I also referred to the dropout percentage (15.3%) in Kothe [29] (About the case which the intervention period (30 days) is about the same as us).

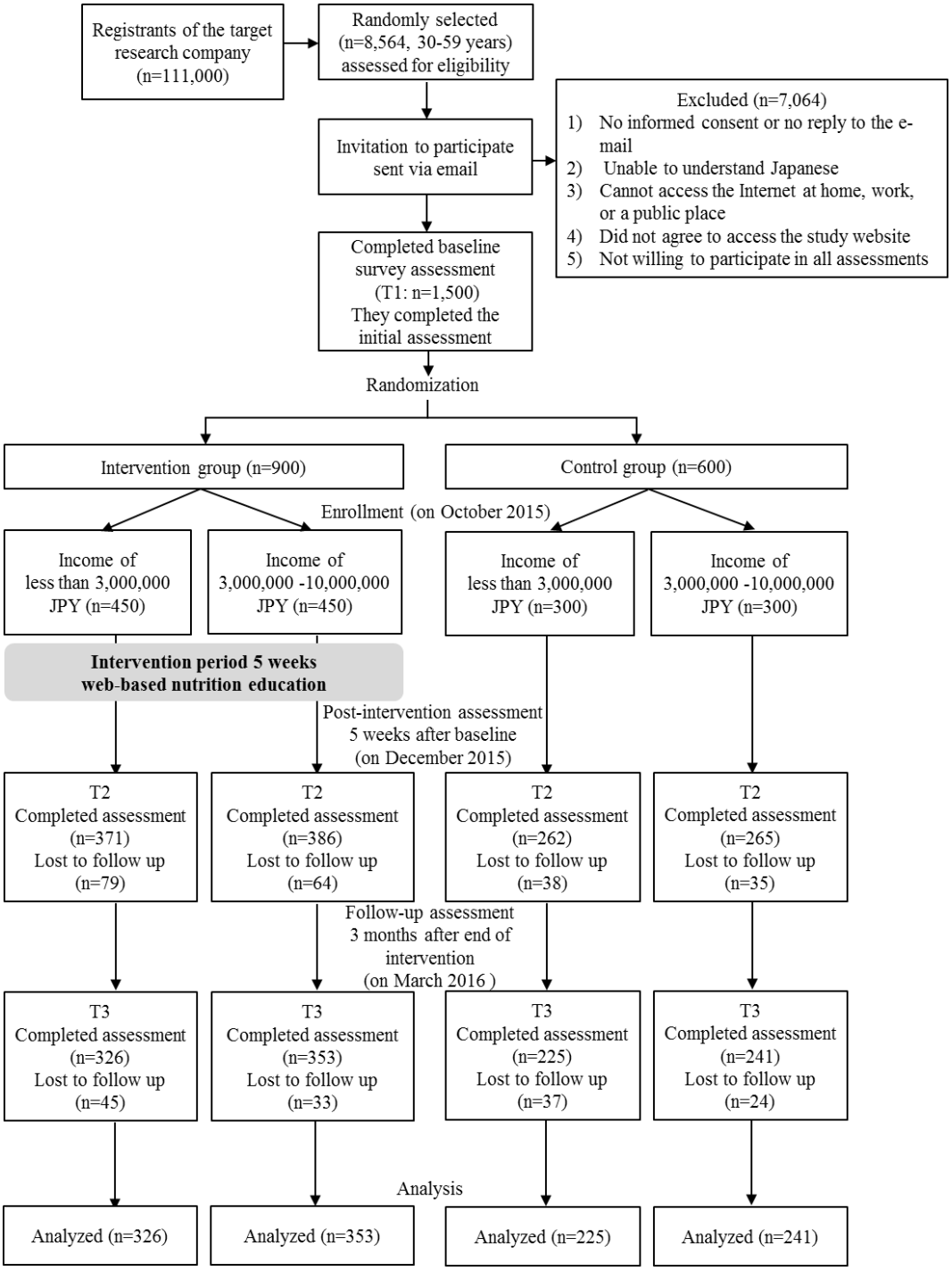

Figure 8.

Flow chart showing participant recruitment, randomization, and evaluation of the Diet and Exercise Practices Project study

2-3. Intervention study procedure and intervention program

The intervention group received emails (about 200 words in Japanese) with health information once a week on Monday between 6:00 and 7:00 a.m. The email contained the following information: “website update announcement,” “previous overview,” “this summary,” and “how to proceed with the site”. For example, for step 2 of the intervention (which took place on the second week of the intervention), the email contained the following information: “Hello, let us look back on your own eating habits is the first step towards health promotion. Step 2 has been updated so I will contact you. i) Diet: Review of Step 1 “How many vegetables dishes (servings) did you eat per day? Let's self-check and see” ii) Diet: Contents of Step 2 “Let's choose one more vegetable dish”, iii) Please see 4 pages of each step in this order, 1) Today's points → 2) Do you know? → 3) Easy to devise → 4) Let's try it! Please look for evident information and let’s choose what you can do.” After completion of the 5-week intervention, participants received an email about the post-intervention survey (T2). Finally, participants received an email about the 3-month follow-up survey (T3).

An interactive website called the “Diet and Exercise Practices Project” (http://healthpromotionqol.com/)” was developed. This is a free website that provides information, three monitoring sheets, and advice about healthy diets, increasing vegetable intake, and preventing lifestyle-related diseases. I hypothesized that achieving an approximately 70 g (1 serving) increase in vegetable intake might help lower-income adults “catch up” in intake compared to middle-income groups, while simultaneously contributing to the partial resolution of the overall deficient vegetable intake in Japanese adults.

The program consisted of a total of 20 pages of content, divided into 5 steps (one step contains 4 pages). The webpage is updated with one step every week. The program was based on the TTM (Figure 9). In step 1, I used the health belief model to encourage movement from the pre-contemplative to the contemplative phase. In steps 2 and 3, social cognitive theory and the theory of planned behavior were used to encourage movement from the contemplative to the preparation phase. In step 4, social cognitive theory and the theory of planned behavior were again used, but this time to encourage movement from the preparation to the action phase. Finally, in step 5, strengthening of social networks and social support were used to promote a shift to the maintenance phase.

The four pages in each step were structured as follows: (1) “Today's point” (including a review of the previous week from the second week onwards), which served as practical

content; (2) “Do you know?” and 3) “Easy to devise,” which were summaries; and (4) “Let's try it !” which involved supporting behavior change by using a worksheet. Figure 10 shows an example of the content on one page (i.e., page 2 for step 2).

The control group surveys took place over the same period as the intervention group surveys. Control group participants received an email from the survey company informing them that they had been randomly assigned to a control group after the baseline (T1). After a 5-week interval, participants received an email requesting them to take part in the post-survey (T2). Three months later, the participants received an email requesting them to participate in a follow-up survey (T3).

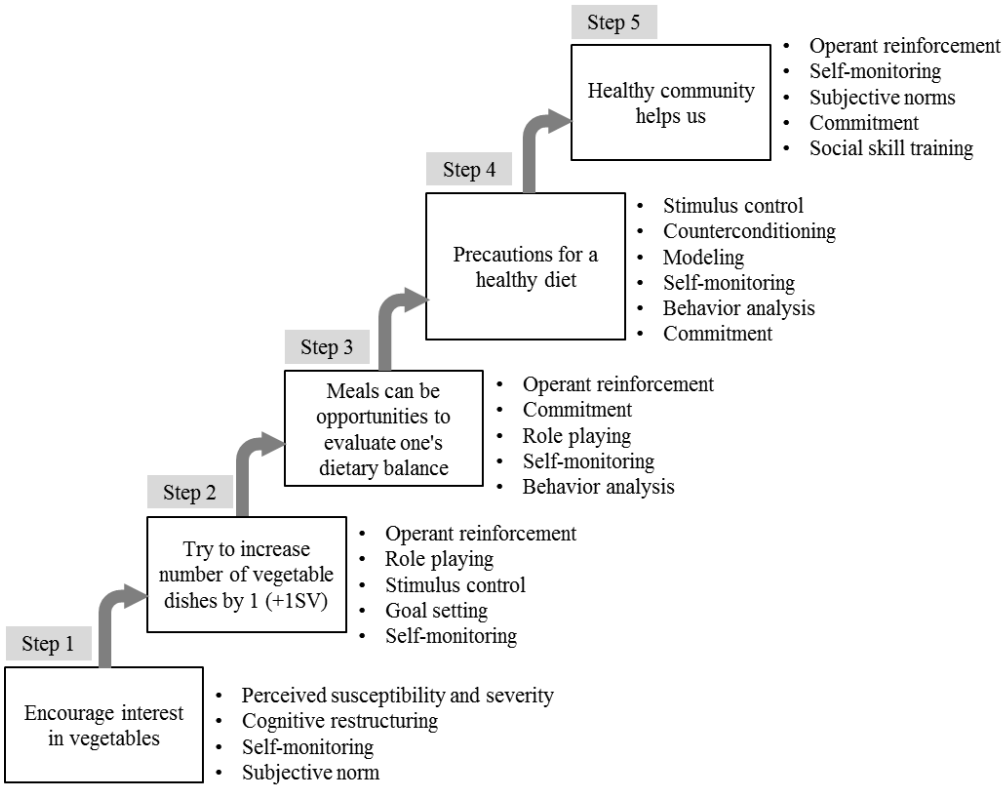

Figure 9.

Five steps and behavioral modification techniques of the nutrition education intervention program. The web intervention period was 5 weeks. Details of the program's theoretical framework are reported in a previously published study protocol [99].

Figure 10.

Example of content of web-based nutrition intervention program (1 page)

2-4. Date collection and outcome measures

Participants were assessed via self-report at three time points: baseline (T1), post-intervention (T2), and follow-up at 3 months (T3). I have listed the details of the assessment items in Table 7. This study evaluated vegetable intake as the main outcome to assess the effectiveness of the nutrition education program. Ozawa suggested that the number of vegetable dishes consumed may be a simpler and more valid measure of vegetable intake compared to a dietary record for both men and women [62]. I presented participants with photographic examples of vegetable dishes (including the size and weight) before they answered the questionnaire. I referred to "The Japanese Food Guide Spinning Top" [55], wherein a dish where vegetables were the main ingredients (70 g) represented 1 serving.

Moreover, I performed a process evaluation of behavior change using various other outcomes, including vegetable eating behavior (per week) [63], stages of change, perceived behavioral control, and knowledge [85]. Perceived behavioral control because it is an important concept [26] in behavior change. For the knowledge item, I showed photographic examples of vegetable dishes (including size and weight) before participants answered. Demographic variables included sex, age, marital status, number of people at home, employment status, and educational status.

Table7. Questionnaire and answers on vegetable intake at three time points.

Variable	Queationnaire	Answer category
Vegetable intake		
	How many vegetable dishes do you usually eat (dishes with vegetables as the main ingredient) per day? One dish is about one small bowl (70 g)"	Number of dishes (servings/day)
Vegetable eating behavior (per week)[a)]		
	The following questions are about your normal dietary habits. Do you eat ample amounts of vegetables (5 small bowls/day, about 350 g)?small dishes/day, about 350 g)?	1. Almost every day 2. 4–5 days/week 3. 2–3 days/week 4. Almost none
Transtheoretical model[a)]		
	Which of the following matches your current dietary condition? Do you eat ample amounts of vegetables (5 small bowls/day, about 350 g)?(5 small dishes/day, about 350 g)?	1. Maintenance (I have continued to eat them for more than 6 months) 2. Action (I have continued to eat them for less than 6 months) 3. Preparation (I sometimes eat or intend to eat within the next 30 days) 4. Contemplation (Although I do not currently eat them, I intend to start eating them within the next 6 months) 5. Precontemplation (I do not eat them and I do not intend to start eating them within the next 6 months)
Perceived Behavioral Control[a)]		
	Do you believe you can do the following things to maintain your health, and your future health, with confidence? Do you have confidence in eating adequate amounts of vegetables (5 small dishes/day, or about 350 g)?	1. A lot of confidence (I have a lot of confidence in eating) 2. Quite a lot of confidence (I have quite a lot of confidence in eating) 3. A little confidence (I have a little confidence in eating) 4. Not a lot of confidence (I do not have a lot of confidence in eating) 5. Very little confidence (I have very little confidence in eating) 6. Not have any confidence (I do not have any confidence in eating)
Knowledge[a)]		
	Did you know that the recommended vegetable intake for maintaining health in adults is 350 g per day?	1. Yes 2. No

[a)] Participants chose one answers that best applied to them.

2-5. Statistical analysis

I compared the groups in terms of baseline sociodemographic characteristics (T1) using the chi-square and Mann-Whitney U tests. Moreover, differences in baseline vegetable intake between participants and dropouts were assessed using unpaired t-tests and one-way ANOVAs. Amount of change in vegetable intake was analyzed using a general linear model. The mean change in vegetable intake was analyzed using Bonferroni-corrected comparisons following one-way ANOVAs for the different combinations of groups and time points. I compared the intervention effect on vegetable intake by group and time using two-way ANOVAs, and calculated the effect sizes ($\eta 2$). Other outcomes concerning vegetables were tested using McNemar's test and the Wilcoxon signed-rank test. The effects of multiple comparison were adjusted for using Bonferroni corrections. Participants lost to follow-up, that is, those who did not complete the T2 (n = 216) or T3 (n = 139) surveys or who were otherwise missing any outcome data, were excluded from the analyses. This resulted in the exclusion of 355 participants (23.6% of those randomly assigned) at baseline. Such an approach is in line with the revised CONSORT guidelines [81], as there are criticisms of and potential bias caused by imputing missing outcome data required for an intention-to-treat analysis. It has been pointed out that when the dropout rate is high, researchers should be cautious about conducting an intention-to-treat analysis. Indeed, in another RCT [45], an intention-to-treat analysis was not carried out because of a high dropout rate (14.9%). Therefore, our analyses were not strictly intention-to-treat. All statistical analyses were performed using IBM SPSS Statistics 21.0. A p-value of .05 was used as the level of significance.

3. Results

Table 8 shows baseline data collected from 1145 participants. The number of participants who completed the intervention in the intervention group was as follows: low-income (n = 326, 72.4%) and middle-income (n = 353, 78.4%). In the control group, the number of participants who completed all three surveys was as follows: low-income (n = 225, 75%) and middle-income (n = 241, 80.3%). There were no differences in characteristics between the intervention group and the control group in either income group, except for marital status and number of people at home in the <3,000,000 JPY. Comparison of baseline characteristics between participants who were excluded and those who were included yielded the following differences: gender (included: men 52.1%, women 47.9%; excluded: men

43.4%, women 56.6%; p = .005) and educational status (included: junior high/high school 26.8%, 2-year college 26.2%, 4-year college/graduate school 47.0%; excluded: Junior high/high school 32.8%, 2-year college 28.4%, 4-year college/graduate school 38.8%; p = .005).

Table 8 Baseline sociodemographic characteristics and vegetable intake of the study participants for adults.

	< 3,000,000 JPY[d)]			3,000,000–10,000,000 JPY[d)]		
	Intervention n = 326 n (%)	Control n = 225 n (%)	p	Intervention n = 353 n (%)	Control n = 241 n (%)	p
Gender[b)]						
Men	169 (51.8)	120 (53.3)	0.795	183 (51.8)	124 (51.5)	0.934
Women	157 (48.2)	105 (46.7)		170 (48.2)	117 (48.5)	
Age[c)]						
30-39 years	106 (32.5)	76 (33.8)	0.385	117 (33.1)	73 (30.3)	0.233
40-49 years	116 (35.6)	88 (39.1)		138 (39.1)	89 (36.9)	
50-59 years	104 (31.9)	61 (27.1)		98 (27.8)	79 (32.8)	
Marital status[b)]						
Not married	217 (66.6)	169 (75.1)	0.037	116 (32.9)	72 (29.9)	0.473
Married	109 (33.4)	56 (24.9)		237 (67.1)	169 (70.1)	
Residential status[a,b)]						
Living together	198 (66.4)	111 (56.6)	0.029	292 (85.6)	194 (82.6)	0.351
Not living together	100 (33.6)	85 (43.4)		49 (14.4)	41 (17.4)	
Employment status[a,b)]						
Not employed	103 (32.5)	61 (28.6)	0.389	74 (21.4)	46 (19.2)	0.603
Employed	214 (67.5)	152 (71.4)		272 (78.6)	193 (80.8)	
Educational status[a,c)]						
Junior high/high school	114 (35.5)	72 (32.3)	0.055	71 (20.3)	47 (19.6)	0.913
2-year college	92 (28.7)	47 (21.1)		93 (26.6)	65 (27.1)	
4-year college/graduate school	115 (35.8)	104 (46.6)		186 (53.1)	128 (53.3)	

[a)] Percentage excludes unknown/other answers. In < 3,000,000 JPY: Number of people at home (n = 28), Employment status (n = 9), Educational status (n = 5) in the intervention group; Number of people at home (n = 29), Employment status (n = 12), Educational status (n = 2) in the control group. In 3,000,000–10,000,000 JPY: Number of people at home (n = 12), Employment status (n = 7), Educational status (n = 3) in the intervention group; Number of people at home (n = 6), Employment status (n = 2), Educational status (n = 1) in the control group.

[b)] Chi-square test

[c)] Mann-Whitney-U test

[d)] 120 JPY = $1 USD in October 2015

Table 9 shows that mean (SD) vegetable intake at each time point. The participants with low income at T1 in the intervention group showed a lower vegetable intake compared to middle-income participants in both the intervention and control groups. The same pattern was found for participants with low income at T1 in the control group. There were no other differences between the groups. I confirmed that there were no differences in baseline vegetable intake between participants who were included in the analysis and those who dropped out ($p = .911$). The mean difference in vegetable intake at T2 also increased in low-income intervention group participants compared to T1 (0.42 servings; 95% CI: 0.11, –0.72 $p < .001$). In the control group among low-income participants, the mean vegetable intake at T2 was not much different from that at T1 (0.05 servings; 95% CI: -0.26, 0.36); the difference between T3 and T1 was also minor (0.03 servings; 95% CI: -0.28, 0.34). For middle-income participants, the mean vegetable intake at T2 was barely different from that T1 (0.04 servings; 95% CI: -0.27, 0.36); the same was true comparing T3 and T1 (0.03 servings; 95% CI: -0.29, 0.34).

Table 9 Mean (SD) and mean difference (95% CI) in each vegetable intake measure at 3 time points.

	< 3,000,000 JPY[e)]			3,000,000–10,000,000 JPY[e)]		
	Intervention n = 326	Control n = 225		Intervention n = 353	Control n = 241	
	Mean ± SD [a,b,c)]		Mean difference (95%CI) [d)]	Mean ± SD [a,b,c)]		Mean difference (95%CI) [d)]
T1	2.08 ±1.49	1.88 ± 1.38		2.42 ± 1.50[fg]	2.44 ± 1.40[fg]	
T2	2.50 ± 1.79	1.93 ± 1.37[h]	0.42 (0.11, 0.72)	2.67 ± 1.46[i]	2.49 ± 1.49[i]	0.25 (-0.02, 0.52)
T3	2.23 ± 1.54	1.91 ± 1.33	0.15 (-0.15, 0.46)	2.47 ± 1.46[j]	2.47 ± 1.44[j]	0.04 (-0.23, 0.31)

[a)] Mean ± SD of servings / day

[b)] General linear model

[c)] One-way ANOVA $p < .05$, Bonferroni-corrected post hoc comparisons using t-test. Significance was based on $p < .05/6=0.008$

[d)] Mean difference (95% CI) in servings/day in intervention group from T1

[e)] 120 JPY = $1 USD in October, 2015

[f)] Significant difference vs. intervention group in <3,000,000 JPY at T1

[g)] Significant difference vs. control group in <3,000,000 JPY at T1

[h)] Significant difference vs. intervention group in <3,000,000 JPY at T2

[i)] Significant difference vs. control group in <3,000,000 JPY at T2

[j)] Significant difference vs. control group in <3,000,000 JPY at T3

Table 10 shows the effect size of vegetable intake by income. Two-way ANOVAs showed that both low-income and middle-income participants had significant main effects of group and time, and a significant interaction. Multiple comparisons (Figure 11) showed that vegetable intake among low-income participants increased between T1 and T2. Although it did not decrease significantly between T2 and T3, the difference between T1 and T3 was not significant. There were no changes in vegetable intake among middle-income when comparing any time point. (Figure 12). However, multiple comparisons revealed that vegetable intake among low-income participants at T1 was lower than that among middle-income participants (T1: $p < .003$). At T2 and T3, the difference between income groups had disappeared (T2: $p = 0.159$, T3: $p = .045$).

Table 10 The effect size (η2) in comparisons of vegetable intake between groups and times using two-way ANOVAs.

	Repeated ANOVA[b,c,d)]								
	Group			Time			Interaction		
Vegetable intake	p	partial η^2	η^2	p	partial η^2	η^2	p	partial η^2	η^2
< 3,000,000 JPY[a,e)]	0.029	0.10	0.04	0.023	0.01	0.01	0.009	0.10	0.01
3,000,000–10,000,000 JPY[a,e)]	0.624	0.00	0.00	0.006	0.01	0.01	0.046	0.01	0.01

[a)] In <3,000,000 JPY group, self-reported vegetable intake at all 3 time points, n = 326 (intervention) and n = 225 (control). In 3,000,000–10,000,000 JPY group, self-reported vegetable intake at all 3 time points, n = 353 (intervention) and n = 241 (control).

[b)] General linear model adjusted for baseline marital status and number of people at home in <3,000,000 JPY.

[c)] Dependent variable, vegetable intake servings

[d)] η^2: effect size low = 0.01, middle = 0.06, high = 0.14

[e)] 120 JPY = $1 USD in October 2015

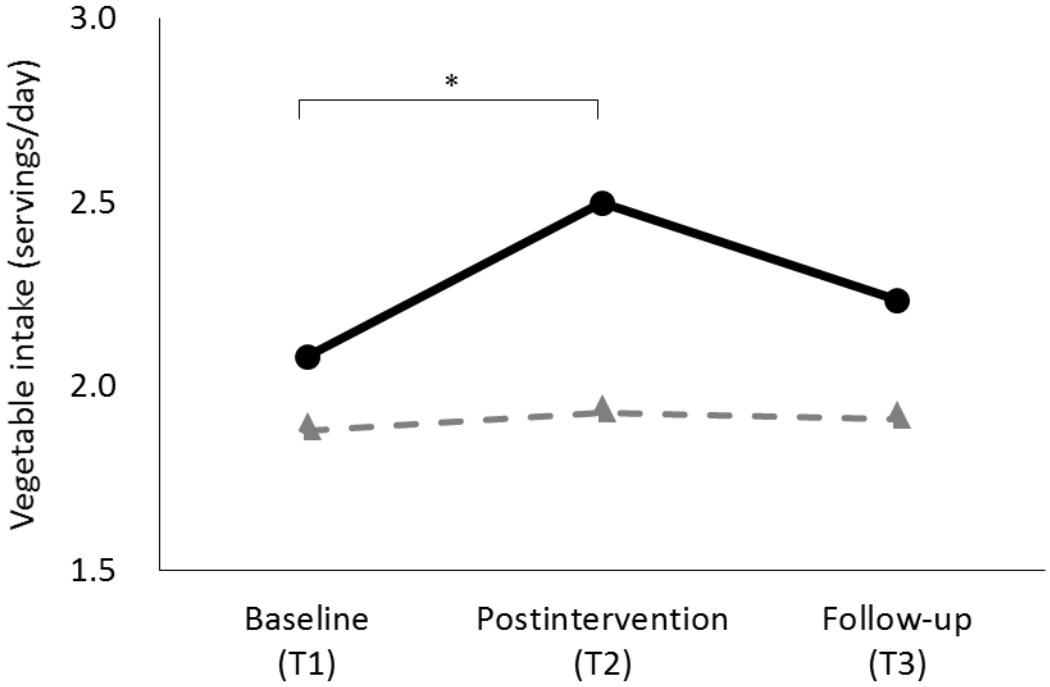

Figure 11.

In the <3,000,000 JPY group, means (SD) of self-reported vegetable intake at baseline (T1), post intervention (T2), and a follow-up at 3 months (T3) in the intervention group (solid line) and control group (dotted line). Data were analyzed by using two-way ANOVAs.

* General linear model, significance was based on $p < .05/3 = .0167$ (Bonferroni-corrected)

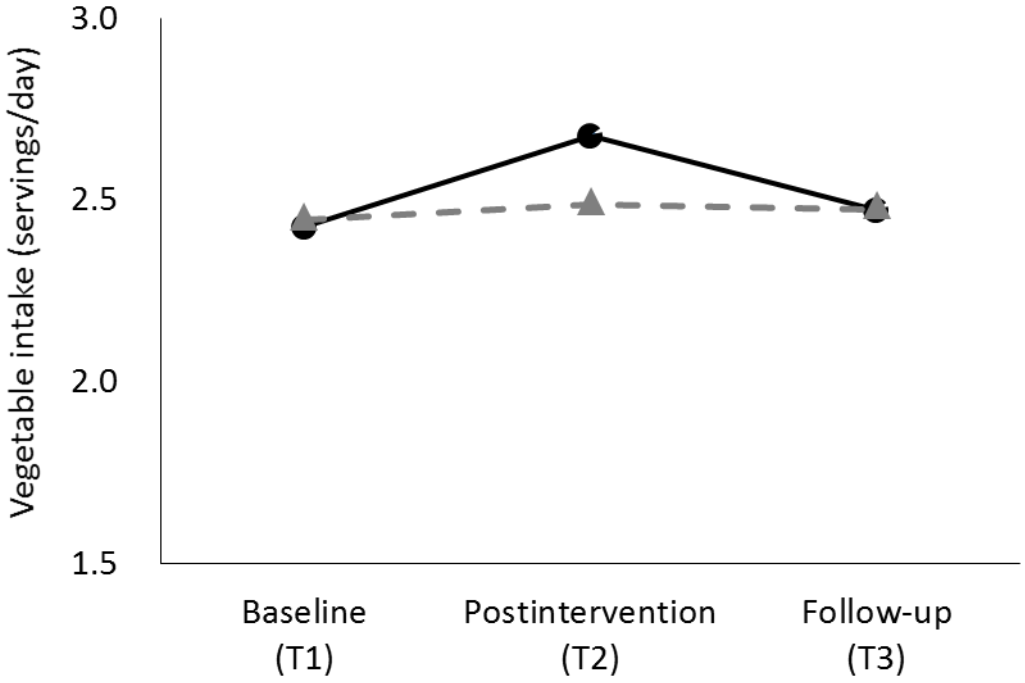

Figure 12.

In the 3,000,000–10,000,000 JPY group, means (SD) of self-reported vegetable intake at baseline (T1), post intervention (T2), and a follow-up at 3 months (T3) in the intervention group (solid line) and the control group (dotted line). Data were analyzed by using two-way ANOVAs.

Tables 11 and 12 show the results for eating vegetables behavior, stage of change, perceived behavioral control, and knowledge of vegetable intake. Low-income participants (<3,000,000 JPY) in the intervention group showed improvements in eating vegetables, stages of change, perceived behavioral control, and knowledge at T2 compared with T1. Furthermore, the improvements in eating vegetables and dietary knowledge were maintained between T2 and T3. In middle-income participants (3,000,000—10,000,000 JPY), only improvements in knowledge were maintained from T1 to T2, and from T1 to T3. However, in the control group, improvements in knowledge were maintained from T1 to T2 and from T1 to T3 among both income groups (All: $p < .001$).

Table 11 Baseline, post-intervention, and follow-up in change in behavior, TTM, perceived behavioral control, and knowledge about vegetable intake in this web-based intervention among < 3,000,000 JPY.

	< 3,000,000 JPY[c)]									
	Intervention n=326					Control n=225				
	T1	T2	T3	p[b)]		T1	T2	T3	p[b)]	
	n (%)	n (%)	n (%)	T1-T2	T1-T3	n (%)	n (%)	n (%)	T1-T2	T1-T3
Eating vegetable behavior[d)]										
Almost every days	24 (7.4)	39 (12.0)	32 (9.8)	<0.001	0.008	14 (6.2)	14 (6.2)	17 (7.6)	0.134	0.005
4-5 days/week	36 (11.0)	52 (16.0)	38 (11.7)			18 (8.0)	21 (9.3)	30 (13.3)		
2-3 days/week	91 (27.9)	97 (29.8)	109 (33.4)			75 (33.3)	79 (35.1)	61 (27.1)		
Almost none	175 (53.7)	138 (42.3)	147 (45.1)			118 (52.4)	111 (49.3)	117 (52.0)		
Transtheoretical mode[a)]										
Maintenance	56 (17.2)	74 (22.7)	65 (19.9)	<0.001	0.271	27 (12.0)	34 (15.1)	40 (17.8)	0.097	0.292
Action	17 (5.2)	16 (4.9)	19 (5.8)			10 (4.4)	19 (8.4)	9 (4.0)		
Preparation	108 (33.1)	123 (37.7)	100 (30.7)			82 (36.4)	62 (27.6)	64 (28.4)		
Contemplation	84 (25.8)	75 (23.0)	83 (25.5)			62 (27.6)	68 (30.2)	69 (30.7)		
Precontemplation	61 (18.7)	38 (11.7)	59 (18.1)			44 (19.6)	42 (18.7)	43 (19.1)		
Perceived behavioral control[d)]										
A lot of confidence	15 (4.6)	24 (7.4)	16 (4.9)	<0.001	0.055	10 (4.4)	9 (4.0)	8 (3.6)	0.319	0.249
Quite a lot of confidence	30 (9.2)	33 (10.1)	38 (11.7)			10 (4.4)	18 (8.0)	23 (10.2)		
A little confidence	49 (15.0)	56 (17.2)	54 (16.6)			33 (14.7)	32 (14.2)	33 (14.7)		
Not a lot of confidence	108 (33.1)	118 (36.2)	109 (33.4)			78 (34.7)	72 (32.0)	75 (33.3)		
Very little confidence	51 (15.6)	42 (12.9)	41 (12.6)			40 (17.8)	40 (17.8)	29 (12.9)		
Not any confidence	73 (22.4)	53 (16.3)	68 (20.9)			54 (24.0)	54 (24.0)	57 (25.3)		
Knowledge										
Yes	106 (32.5)	174 (53.4)	177 (54.3)	<0.001	<0.001	60 (26.7)	90 (40.0)	93 (41.3)	<0.001	<0.001
No	220 (67.5)	152 (46.6)	149 (45.7)			165 (73.3)	135 (60.0)	132 (58.7)		

[a)] Transtheoretical model (TTM): 5 stage of change = Maintenance, I have continued to eat them for more than 6 months; Action, I have continued to eat them for less than 6 months; Preparation, I sometimes eat them or intend to eat them within the next 30 days; Contemplation, Although I do not eat them currently, I intend to start eating them within the next 6 months; Precontemplation, I do not eat them and I do not intend to start eating them within the next 6 months.

[b)] Ordinal scale; Wilcoxon signed rank test, Bonferroni-corrected post hoc comparisons made using Mann-Whitney-U test ($p < .05/3=.0167$). Nominal scale; McNemar's test, Bonferroni-corrected post hoc comparisons made using chi-square test ($p < .05/3 = .0167$).

[c)] 120 JPY = $1 USD in October 2015

[d)] The percentage might not reach 100% in some cases because the rate was rounded off.

Table 12 Baseline, post-intervention, and follow-up in change in behavior, TTM, perceived behavioral control, and knowledge about vegetable intake in this web-based intervention among 3,000,000 –10,000,000 JPY.

	3,000,000 –10,000,000 JPY[c)]									
	Intervention n=353					Control n=241				
	T1	T2	T3	p[b)]		T1	T2	T3	p[b)]	
	n (%)	n (%)	n (%)	T1-T2	T1-T3	n (%)	n (%)	n (%)	T1-T2	T1-T3
Eating vegetable behavior[d)]										
Almost every days	32 (9.1)	33 (9.3)	34 (9.6)	0.383	0.116	19 (7.9)	19 (7.9)	18 (7.5)	0.029	0.018
4-5 days/week	50 (14.2)	56 (15.9)	73 (20.7)			38 (15.8)	44 (18.3)	48 (19.9)		
2-3 days/week	125 (35.4)	134 (38.0)	120 (34.0)			86 (35.7)	103 (42.7)	100 (41.5)		
Almost none	146 (41.4)	130 (36.8)	126 (35.7)			98 (40.7)	75 (31.1)	75 (31.1)		
Transtheoretical mode[a,d)]										
Maintenance	87 (24.6)	81 (22.9)	77 (21.8)	0.254	0.135	49 (20.3)	64 (26.6)	52 (21.6)	0.065	0.241
Action	23 (6.5)	24 (6.8)	42 (11.9)			12 (5.0)	15 (6.2)	21 (8.7)		
Preparation	106 (30.0)	149 (42.2)	128 (36.3)			96 (39.8)	84 (34.9)	91 (37.8)		
Contemplation	94 (26.6)	72 (20.4)	64 (18.1)			61 (25.3)	48 (19.9)	54 (22.4)		
Precontemplation	43 (12.2)	27 (7.6)	42 (11.9)			23 (9.5)	30 (12.4)	23 (9.5)		
Perceived behavioral control[d)]										
A lot of confidence	19 (5.4)	26 (7.4)	19 (5.4)	0.579	0.151	13 (5.4)	18 (7.5)	8 (3.3)	0.041	0.954
Quite a lot of confidence	53 (15.0)	44 (12.5)	47 (13.3)			33 (13.7)	36 (14.9)	31 (12.9)		
A little confidence	71 (20.1)	71 (20.1)	64 (18.1)			45 (18.7)	39 (16.2)	47 (19.5)		
Not a lot of confidence	122 (34.6)	132 (37.4)	135 (38.2)			81 (33.6)	94 (39.0)	100 (41.5)		
Very little confidence	48 (13.6)	47 (13.3)	43 (12.2)			45 (18.7)	36 (14.9)	33 (13.7)		
Not any confidence	40 (11.3)	33 (9.3)	45 (12.7)			24 (10.0)	18 (7.5)	22 (9.1)		
Knowledge										
Yes	109 (30.9)	186 (52.7)	191 (54.1)	<0.001	<0.001	69 (28.6)	90 (37.3)	110 (45.6)	<0.001	<0.001
No	244 (69.1)	167 (47.3)	162 (45.9)			172 (71.4)	151 (62.7)	131 (54.4)		

[a)] Transtheoretical model (TTM): 5 stage of change = Maintenance, I have continued to eat them for more than 6 months; Action, I have continued to eat them for less than 6 months; Preparation, I sometimes eat them or intend to eat them within the next 30 days; Contemplation, Although I do not eat them currently, I intend to start eating them within the next 6 months; Precontemplation, I do not eat them and I do not intend to start eating them within the next 6 months.

[b)] Ordinal scale; Wilcoxon signed rank test, Bonferroni-corrected post hoc comparisons made using Mann-Whitney-U test ($p < .05/3=.0167$). Nominal scale; McNemar's test, Bonferroni-corrected post hoc comparisons made using chi-square test ($p < .05/3=.0167$).

[c)] 120 JPY = $1 USD in October 2015

[d)] The percentage might not reach 100% in some cases because the rate was rounded off.

4. Discussion

4-1. Main Discussion

A strength of this study was its RCT design and stratification by income to investigate the reduction in vegetable intake disparity. The main finding was that vegetable intake and related processes among low-income participants improved, thus reducing the existing disparities with the middle-income group. I suggest that this web-based nutrition education program based on multiple health behavior theories is an effective intervention for low-income adults. To our knowledge, this is the first web-based intervention study to investigate reductions in vegetable intake disparities in adults. Further improvements in the intervention program are necessary to increase intake and maintain that increase throughout a follow-up period among middle-income adults.

The vegetable intake among low-income participants increased by 0.42 servings after the intervention, which helped reduce the vegetable intake disparity between incomes. Additionally, behavioral change processes such as dietary behavior, stages of change, self-efficacy, and knowledge improved. Most past web-based studies were conducted outside Japan. Bensley et al. [47] reported an increase of 0.59 servings after a web-based nutrition education for 6 months in adults, Sternfeld et al. [50] an increase of 0.18 servings using an email intervention for 16 weeks in employees, and Kothe et al. [29] an increase of 0.84 servings using an email intervention for 30 days in undergraduate students. Thus, in all three of these studies, the intervention led to increased fruit and vegetable intake. However, importantly, these studies evaluated vegetables and fruit in the same category. “The Japanese Food Guide Spinning Top,” a Japanese food guide, classifies vegetables and fruits in different categories [55]. This study showed a clearly positive intervention effect for vegetable intake only. Past studies in Japan showed that nutrition education interventions increased vegetable intake by 0.32 servings in 24 weeks among male workers [42], and by 0.20 SV one year later in employees [41]. The improvements in vegetable intake and improved behavioral change processes are further strengths of this study. Our results contributed to reducing disparities in vegetable intake between low- and middle-income by using a very short-term (5-week) web-based intervention.

The nutrition education program also two important strengths. First, the program was based on the stages of change, which are thought to be applicable to nutrition interventions [100]. Many previous studies have found support for methods based on multiple

health behavior theories aimed at increasing vegetable intake [44, 101]. In this study, participants were assumed to be in the pre-contemplation stage baseline (Figure 9). As improved self-efficacy is essential for behavior change, I made sure that all steps of the program focused on improving self-efficacy. I expect that the composition of this program helped increase vegetable intake among low-income individuals, who may have had low self-efficacy (PBC).

Second, Park et al. [49] reported that 88% of participants completed their 30-day web intervention for adults. Kothe et al. reported 85% [29] and 80% [30] intervention completed participants with a 30-day e-mail intervention in undergraduate students. This study had a roughly equivalent number of participants who completed the intervention (low income: 82.4%, middle income: 85.7% at T2). This is possibly because participants received an e-mail including a weekly summary of the program and informative support. Additionally, the intervention was highly accessible (e.g., time, place, and situation) because participants could complete the activities use their smartphone or personal computer. There are extremely few previous reports on web-based interventions for Japanese adults [53]; as such, our web-based nutrition education program is not only highly effective, but also provides novel evidence.

The improvement in vegetable intake in low-income participants in the intervention group disappeared by the three-month follow-up. This might have been because I used only one theoretical approach (see Step 5) to promote the change from the action to maintenance stage. It is therefore necessary to strengthen this aspect of the intervention. For example, Japanese traditional food culture distinguishes between seasonal dishes as well as foods for all four seasons. I could distribute nutrition information and recipes about seasonal foods such as vegetables during a follow-up period in order to promote continued vegetable intake. In addition, I could regularly tweet reviews of the program content, and send reminders of the effort needed to prevent reversal of behavior change. Behavior change can be regarded as habitual if it is maintained for more than six months. After observing the program-related improvements in this study, it is worth attempting these approaches during follow-up to maintain the intervention effect.

Vegetable intake among middle-income participants might not have increased after the intervention because of the program's use of an inappropriate approach to behavior change for this income group. For example, food access and perceptions of the food environment might differ depending on income [33]. Perceived behavioral control, which was the focus of

this program [99], has been found to be low among low-income women [31]. Thus, a program focusing on perceived behavioral control might have promoted ingestion of vegetables up to a certain amount. For further improvement, it is necessary to identify the factors affecting vegetable intake according to income and develop more appropriate intervention methods.

The reason for the low effect sizes was probably the smaller variety of content and shorter intervention periods than in previous studies. The effect size of a 30-day nutrition education intervention by e-mail in undergraduate students [29] was roughly the same as in this study. However, Alexander et al. [51] found medium effect sizes when using a website targeting adults. Their program had a rich variety of contents, such as nutrition education using a short video and audio files, and presenting 300 fruit and vegetable-based recipes. Furthermore, the intervention period was one year, which was considerably longer than was ours. The content of our program is a web site of about 20 pages containing information and worksheets combining text and images. I expect larger effects if I increased the variety of the content and the length of the intervention period.

4-2. Limitations and implications

Some limitations warrant discussion. First, I were careful to extract samples matching the Japanese demographic distribution. Nonetheless, our participants had a higher education level compared to the census [102]. Second, I could not identify the factors that improved the control group's knowledge. Possibly, they acquired the knowledge during the survey, or they were exposed to health promotion strategies elsewhere. However, the results show that behavioral change does not occur merely through improving knowledge. Third, the design was not strictly intention-to-treat. Using an approach to impute missing outcome data for the relatively large number of dropouts (23.6% of the sample) can cause potential biases. I analyzed them in comparison to their originally assigned group, and confirmed that there were no baseline differences in vegetable intake between the participants included in the analysis and the dropouts. Fourth, regrettably, I have no data on the weight status, health status, or chronic diseases of participants. I did not assess body weight status because the validity of self-assessment of body weight is unknown. Furthermore, a diagnosis by a doctor is necessary for to determine the presence or absence of a chronic disease. Exercise is currently being investigated by other project teams; therefore, I could not handle the data on exercise. Other relevant data, such as frequency of intake of other foods, should be examined in the future. This would help in

generalizing the results of our study. Fifth, I could not investigate the relationship between the intervention dose and its effect. Regrettably, the website set a common password for all participants, as I had insufficient research funding and were unable to handle personal information such as individual ID and password settings. By developing applications or other tools in cooperation with companies in the future, I would be able to further develop this line of research. Finally, the results can only apply at the moment to individuals aged 30–59 years and with incomes less than 10,000,000 JPY, thus limiting the generalizability of the findings.

This program has the following implications. The intervention succeeded in increasing vegetable intake without being restricted to a single geographical area. This shows the possibility that our nutrition education program can spread widely in the future. Furthermore, the program has a systematic composition, containing five steps of 4 pages of content each: 1) Today's point, 2) Do you know? 3) Easy to devise, and 4) Let's try it! It is worth investigating whether the program can achieve the same effect using other methods (e.g., higher frequency of emails (20 times), face-to-face delivery of content). Further research might aim to clarify which components of web-based interventions or the program framework contribute to reducing vegetable intake disparities. In conclusion, the findings from this RCT indicate that this web-based nutrition education program can increase vegetable intake among low-income adults, thus contributing to the reduction in vegetable intake disparities.

Ⅸ. General Discussion

Appropriate vegetable intake brings health benefits such as the prevention of lifestyle diseases and a decrease in their severity. However, many people do not meet the recommended vegetable intake in many countries. Japanese people who do not meet the recommended intake of vegetables account for about two-thirds of the population [21], and this proportion is higher for lower income groups [23]. The disparity in dietary intake caused by the income disparity is an urgent global issue [5, 6]. To solve this problem, I examined the effect of reducing the disparity in vegetable intake through a population intervention study. As a result, the nutrition education program, which was developed based on the intervention plan that extracted relevant factors of vegetable intake, increased the intake of vegetables in the low-income category, reducing the disparity. This result may contribute to solving the problem of disparity in vegetable intake, and is thus of high international interest.

A systematic review of the literature revealed that previous studies employed multiple health behavior theories to increase vegetable intake [39, 40]. I structurally examined the relationship between several theories and elements to create an intervention plan for promoting desirable vegetable intake (Study 1-1). Based on our results, I focused on the following three points. 1) It was predicted that as the stage of change advanced, a change in vegetable intake behavior would be promoted. Therefore, the program should progress in the order of the stages of change. 2) Behavioral techniques effective in improving the PBC that most affects the progression of the stages of change were used. (PBC is highly likely to directly affect behavioral change in the low-income category.) 3) Instead of only vegetables, the aim was to develop a program based on the theme of “meal patterns” that include grain dishes, fish and meat dishes, and vegetable dishes. In particular, many people in this group with low PBC earn less than 3 million yen, which supports the fact established in previous studies that PBC is as important as having a low income [31]. Numerous previous studies predicting vegetable intake based on TPB reported the great influence of PBC and [27-29] shared global views. In addition, the elements of the theory included grain dishes, fish and meat dishes, and vegetable dishes. This indicates that the desirable vegetable intake behavior does not only consist of vegetables, but could be influenced by unique Japanese dietary patterns, including eating grain dishes, fish and meat dishes, and vegetable dishes. Investigating a structural model that predicts a target behavior change and preparing a program

focusing on important theories and elements may yield practical research results that link theory and practice.

Each municipality is working on improving various food environments according to policies concerning public health nutrition to encourage people to change their behavior (Study 1-2). Therefore, perceiving a well-maintained food environment in the neighborhood may promote access to one. In this group, the perception of reasonable prices for balanced food, and the perception of the social capital of food determined by local culture and tradition such as the atmospheres of neighborhoods, may promote vegetable intake. Approximately 60% of Japanese adults reported that "price" was an important element when purchasing perishables [74]; therefore, I infer that the perception of a reasonable price is important in changing vegetable intake. In addition, cherishing the connection of people through food by means of its social capital is an important concept indicating the healthy diet of the Japanese. To verify the possibility that cognition of these food environments will bring about desirable vegetable intake behavior, practical intervention research is needed.

Recently, the use of ICT as an international health policy and educational tool has been promoted. The use of ICT in nutrition education has many merits for both learners and supporters, and is expected to spread in the future. To disseminate the academic outcomes of practical intervention studies using ICT, it is necessary to prepare intervention protocols that meet international standards. Face-to-face nutrition education using the web as a tool has succeeded in increasing vegetable intake [47, 48, 54]. However, in the face-to-face style, it is not possible to segment the target according to income index based on ethnic and social background, and studies on the disparity reduction effect have not yet been conducted. Therefore, by 1) grasping income indicators; 2) securing a sufficient number of samples; 3) eliminating contamination of the intervention effect, which is a face-to-face task such as regional intervention; 4) and extracting matching samples from demographic statistics, I created an intervention protocol to recruit targets via the web [99]. In practice intervention research, reports that satisfy qualitative criteria such as SPIRIT statements [82] are the first in our country and important internationally.

I developed an intervention protocol that meets international standards and verified the disparity reduction effect of vegetable intake due to differences in income [103]. The continuation rate of our five-week nutrition education program according to our intervention protocol was high (low income: 82%, middle income: 86%), and confirmed practicality. The

practicalities include e-mail notifications of weekly program updates, content that can be stepped up in the stage of change every week, and browsing the site, which can be traced back to past contents. The amount may be influenced by ingenuity such as making the length 30 seconds to 1 minute long so that it is not too long. Between T1 and T2, PBC and stage of change of the low-income category improved, and vegetable intake increased (0.42SV). Furthermore, the gap between the vegetable intake of the middle-income category also reduced, confirming effectiveness. Few reports have succeeded in improving outcomes according to a series of processes as in this research. In the Japanese intervention, based on information from Japanese workplace cafeterias, vegetable intake increased to 0.32 SV [42] in 24 weeks and 0.20 SV [41] in one year. Compared to previous Japanese studies, the desired effect of the short-term practical intervention will have a major future impact on this research field. However, to continue the intervention effect and further increase the vegetable intake of the middle-income category, it is necessary to explore other support methods. In addition, the reversal of behaviors after the intervention is not a participant of this research alone, but a long-standing problem in the field of health education. It is worthwhile to continue this work for the sake of continuity.

As the participant of this research is limited to the survey company monitor, caution in the interpretation and generalization of the results is needed. From now on, I will use this program to educate local people and enterprises on food (distance education by tablet and smart phone, delivery of e-mail magazine, 4 pages (1 time) × 5 times classroom nutrition education, booklet for education). It is also possible to further develop the program. Verification in the practical field targeting various groups will greatly contribute to solving the disparity in international vegetable intake.

Ⅹ. Conclusions

In this study, preparation factors and environmental cognitive factors related to behavioral change were examined. Based on the results, a nutrition education program and collective intervention protocol were created. I confirmed the practicality and effectiveness of a group intervention program aimed at reducing the disparity in the intake of vegetables developed according to a series of intervention plans.

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Abbreviations list

World health organization (WHO)

Perceived behavioral control (PBC)

Normed fit index (NFI)

Comparative fit index (CFI)

Root mean square error of approximation (RMSEA)

Randomized controlled trial (RCT)

Transtheoretical model (TTM)

Analyses of variance (ANOVA)

Servings (SV)

Confidence interval (CI)

Socio-economic status (SES)

Aichi Gerontology Evaluation Study Cohort (AGES)

Cardiovascular disease (CVD)

The World Cancer Research Fund and the American Institute for Cancer Research (WCRF)

Standard deviation (SD)

Relative risk (RR)

Hazard ratio (HR)

Theory of planned behavior (TPB)

Body mass index (BMI)

Japan Public Health Center-based Prospective Study (JPHC)

Adjusted odds ratios (AOR)

Information and communications technology (ICT)

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