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Simulation of the fruit and vegetable intakes meeting the dietary reference intakes of Japanese adults from the National Health and Nutrition Survey

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Fruit and vegetable intake has been associated with a reduced risk of noncommunicable diseases, however, few studies have assessed the necessary intake of fruits and vegetables to meet nutrient reference values for the dietary reference intake. This study aimed to estimate the amount of fruit and vegetable intake necessary to meet the reference values of the dietary reference intakes of Japanese people for selected nutrients using the current national dietary intake data for the Japanese adults. We used the data from 4927 Japanese adults aged 20 years and over who participated in the dietary survey in the 2019 National Health and Nutrition Survey. Nine scenarios (70–90% of Japanese adults consuming between 100 and 200 g of fruit) were used to predict the recommended average intake of fruits and vegetables that met the reference values of the dietary reference intakes of Japanese people for dietary fibre, vitamin A, and potassium as fruits and vegetables are the main sources of these nutrients. The scenario in which more than 90% of adults consumed 200 g of fruits per day would almost meet the values in the dietary reference intakes of Japanese people for dietary fibre and vitamin A excluding potassium. The estimated average intake of fruit and vegetables in this scenario was 200 g and 350 g, respectively. Our scenarios demonstrated that an intake of 200 g of fruits and 350 g of vegetables, which have previously been reported to reduce disease risk, would be sufficient to meet the values in the dietary reference intakes of Japanese people of most nutrients, mainly obtained from fruits and vegetables. Further research is needed to examine policies and interventions to increase fruit and vegetable consumption in the Japanese population.

Keywords Fruit, Vegetable, Dietary reference intakes, Dietary guideline, National Health and Nutrition Survey

Abbreviations

BMI	Body mass index
CVDs	Cardiovascular diseases
DG	Tentative dietary goal for preventing lifestyle-related diseases
DRIs	Dietary Reference Intakes for Japanese
EAR	Estimated average requirement
EER	Estimated energy requirement
NCDS	Non-communicable diseases
NHNS	National Health and Nutrition Survey in Japan
OECD	Organization for Economic Co-operation and Development
STFCJ	Standard tables of food composition in Japan

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Background

Fruit and vegetable intake has been associated with a reduced risk of non-communicable diseases (NCDs), including heart disease, blood pressure, diabetes, and cancer[1–4]. Therefore, food-based dietary guidelines worldwide, which aim to identify nutrients associated with public health problems and select appropriate foods to modify nutrient intake, recommend increased consumption of fruits and vegetables[5]. However, because the contribution of dietary factors to disease varies among countries and regions due to differences in food culture and dietary patterns[6], it is necessary to consider the target amounts of fruits and vegetables that can reduce disease risk and provide adequate nutrient intake, considering the dietary patterns and food culture of people living in each country and region.

In Japan, Health Japan 21, a national health initiative promotion for 10 years that started in 2000, was followed by Health Japan 21 (the second term), which set targets for increasing the intake of fruits and vegetables to meet the reference values for dietary fibre, vitamin C, and potassium, which were the main sources of intake of fruits and vegetables for Japanese people at the time, with the aim of reducing the risk of NCDs[7,8]. Specific goals included reducing the proportion of individuals consuming less than 100 g of fruit and increasing the average vegetable intake to 350 g[7,8]. However, the dietary intake and dietary patterns of Japanese people have changed significantly over the past 20 years[9,10]. Thus, simulations are being conducted to determine the appropriate fruit and vegetable intake for the Japanese population to reduce health risks, and it has been reported that the consumption of 200 g of fruits and 350 g of vegetables may reduce the risk of NCDs such as cardiovascular diseases (CVDs), kidney diseases, and diabetes[11,12]. These findings suggest that there is a substantial need to increase fruit consumption beyond the current targets.

Recently, as dietary patterns among Japanese people have changed and diversified[10], fruits and vegetables have become the main sources of vitamin A and folate[13]. However, no studies have assessed the necessary intake of fruits and vegetables to meet these nutrient reference values for the dietary reference intakes (DRIs) of Japanese people[14]. The target amounts for fruits and vegetables in the current dietary guidelines are based on reports focusing on their association with non-communicable disease risk [7,8]. Although it is expected that a more effective strategy to promote intake could be implemented by evaluating the contribution of fruit and vegetable intake to nutrient intake based on the nutrient reference values in the DRIs, there is insufficient evidence to set target amounts for daily fruit and vegetable intakes, that meet the DRIs. Therefore, this study aimed to estimate the intake of fruits and vegetables required to meet the reference values for nutrients (vitamin A, dietary fibre, vitamin C, folate, and potassium), for which fruits and vegetables are the main sources, using dietary intake data for the Japanese population from the National Health and Nutrition Survey (NHNS) based on scenarios with varying levels of fruit intake.

Methods

Data sources

We used data from Japanese adults aged 20 years and over who participated in the dietary survey in the 2019 NHNS (n = 4927), which is the latest research data available. Until April 2022, the adult age in Japan was set at 20 years[15], and the same rule was also applied to the National Health and Nutrition Survey reports. The purpose of this study is to simulate the intake levels of vegetables and fruits required to meet the Dietary Reference Intakes (DRI) for nutrients primarily obtained from these foods, based on representative dietary intake data for Japanese adults. Therefore, no exclusion criteria other than age were applied. The sex and age category of participants were shown in Supplemental Table 1.

The NHNS is a nationally representative cross-sectional annual household-based survey conducted by local public health centres under the supervision of the Ministry of Health, Labour, and Welfare[16]. Details of the NHNS survey design have been described elsewhere[16,17]. Briefly, the NHNS consists of a physical examination, dietary survey, and lifestyle questionnaire, and the surveys are conducted in November. Participants were all family members (aged ≥ 1 year as of 1 November of the survey year) in households residing in 300 unit blocks that were randomly selected from the unit blocks of the 2019 Comprehensive Survey of Living Conditions. However, some areas of Nagano Prefecture were excluded because the survey was not conducted during Typhoon Hagibis in 2019[13]. The household response rate for the 2019 NHNS was 63.5%.

This survey was conducted according to the guidelines laid down in the Declaration of Helsinki, and all participants provided informed consent to the local government based on the Health Promotion Act[18]. Based on official application procedures under Article 33 of the Statistics Act, we obtained approval from the Ministry of Health, Labour and Welfare, Japan, to use individual-level data from the NHNS for this study. Approval from an institutional review board was not required in accordance with the Ethical Guidelines of Epidemiological Research.

Dietary survey

A dietary survey was conducted using one-day semi-weighed household dietary records, excluding Sundays and public holidays[16]. Trained fieldworkers (mainly registered dieticians) explained how to complete the dietary records to the main recordkeepers (usually responsible for preparing meals) in each household. The main recordkeepers weighed all foods and beverages consumed by each family member, as well as food waste and leftovers, and recorded their names and weights on the recording forms. Additionally, the main recordkeepers recorded the approximate proportion of food consumed by each family member when the members shared food from the same dish to estimate individual intake. If weighing was not possible (i.e., the meal was consumed away from home), the main recordkeepers asked the family members in detail about the name of the restaurant, the name of the dish they ate, the foods included in the dish, their portion sizes and amounts, and the amount they had left.

The trained fieldworkers revisited each household after the dietary record day and checked for missing information and errors. For foods and beverages that were not measured, the trained fieldworkers converted the estimates of portion sizes or quantity of foods into food weights from the information provided by the main recordkeepers and coded each food item according to the NHNS food number lists based on the Standard Tables of Food Composition in Japan[19] to calculate the intake of energy and nutrients. The trained fieldworkers finally entered the collected dietary intake data using a software specifically developed for the NHNS, and the data were checked by trained investigators at the central office to create an overall dietary dataset[16]. Energy and nutrients were calculated based on the Standard Tables of Food Composition in Japan 2015 edition[19].

Classification of fruit and vegetable groups[16]

The classification of fruits follows the NHNS definition, including fresh fruits, dried fruits, and fruit juices; however, it excludes jams. Additionally, the classification of vegetables aligns with the definition used in the NHNS, which encompasses green-yellow vegetables, pale-coloured vegetables, vegetable juices, and pickles; however, it excludes tubers, mushrooms, and seaweed.

Simulation of the fruit and vegetable intakes

Simulation calculations were conducted using Microsoft Excel, which allowed transparent step-by-step estimation of nutrient intakes under each fruit intake scenario. While the computational platform was simple, the analysis is grounded in nationally representative NHNS data, which provides robust estimates at the population level.

Step 1

Initially, the current intakes of dietary fibre, vitamin A, folate, vitamin C, and potassium from fruits and vegetables among Japanese adults were calculated. Regarding folate and vitamin C, since the current intake among Japanese adults already exceeded the DRIs (2020 edition) reference values[14], these nutrients were excluded from the simulation.

Step 2

The simulation scenarios were as follows. As previously mentioned, studies have suggested that consuming 200 g of fruits and 350 g of vegetables can potentially reduce the risk of NCDs such as CVDs[11,12]. The Japanese health promotion initiative, Health Japan 21 (the second term), had set goals of reducing the proportion of individuals consuming less than 100 g of fruits per day to 30%, and increasing daily vegetable intake to at least 350 g. However, the current average intake of fruits and vegetables is 100 g and 281 g, respectively (Supplemental Table 2), with the proportion of individuals consuming less than 100 g of fruits remaining above 60% for over a decade (Table 1). Therefore, this simulation was based on the current goal of "more than 70% of individuals consuming over 100 g of fruits," proposing scenarios where "over 80% or 90% consume more than 100 g of fruits", "over 70%, 80%, or 90% consume more than 150 g of fruits", and "over 70%, 80%, or 90% consume more than 200 g of fruits". The intake of dietary fibre, vitamin A, and potassium from fruits under these nine scenarios was estimated based on current fruit consumption patterns in Japan. The estimations were as follows. For those who currently consume excess fruit in each scenario, the actual intake values were applied to the simulation. Assuming that the remaining individuals who did not meet the target would consume the target intake, the target intake (the minimum amount reaching the target) was calculated (average intake for each nutrient of those exceeding the target/average fruit intake of those exceeding the target × the target fruit intake), and the amount of each nutrient intake from the fruit if the fruit intake assumed in the scenario was calculated. For example, in the scenario where over 80% of the participants consumed more than 150 g of fruit from the NHNS 2019 participants (n = 4927), those consuming over 150 g (n = 1321) and those consuming less (n = 3606) were identified. Nutrient intake from fruits was calculated for both groups. To simulate a scenario in which 80% of participants (n = 3942) consume more than 150 g, the difference in the number of people who consumed more than 150 g (n = 1321) and the number of people in 80% of all participants included in the analysis was determined, and their nutrient intakes were projected by assuming an increased consumption of 150 g. If they had already exceeded 150 g, the current average nutrient intake of these participants was used. For the remaining 20% (n = 985) that did not meet the target, it was assumed that they continued consuming at their current lower intake levels, estimating nutrient intake from fruits accordingly.

Step 3

The estimated nutrient intake from fruits assumed from each scenario in Step 2 was added to the current nutrient intake from sources other than fruits among Japanese adults, and the amounts of dietary fibre (tentative dietary goal for preventing lifestyle-related diseases: DG), vitamin A (estimated average requirement: EAR), and potassium (DG), which were insufficient to meet the reference values of the DRIs (2020 edition) for Japanese adults[14] were calculated. The additional vegetable intake required to meet any deficiencies was estimated by assuming the current vegetable consumption patterns (deficient nutrient amount/current nutrient intake from vegetables × current average vegetable intake). The total vegetable intake required to meet the DRIs under each scenario was calculated by adding the required increase in the current average vegetable intake. The average fruit intake in each scenario was also estimated.

Results

Table 2 shows the proportion of individuals who consume less than 100g of fruit per day, and who do not meet the recommended daily intake of 350g of vegetables. The percentage of individuals who consumed less than 100g of fruit and less than 350g of vegetables was 85.7%.

	10 th percentile	25 th percentile	50 th percentile	75 th percentile	90 th percentile
Energy (kcal/day)	1247	1529	1861	2239	2669
Protein (g/day)	44	55	69	86	104
Fat (g/day)	30	42	58	76	95
Carbohydrate (g/day)	156	196	242	294	348
Dietary fibre (g/day)	10.6	13.8	18.0	22.8	27.9
Vitamin A (μgRAE/day)	147	243	397	599	882
Vitamin D (μg/day)	0.8	1.7	3.6	9.8	18.4
Vitamin E (mg/day)	3.1	4.5	6.3	8.7	11.3
Vitamin K (μg/day)	64	111	197	348	505
Vitamin B_1 (mg/day)	0.5	0.6	0.9	1.2	1.5
Vitamin B_2 (mg/day)	0.6	0.8	1.1	1.5	1.8
Niacin (mg/day)	18	23	30	38	47
Vitamin B_6 (mg/day)	0.6	0.8	1.1	1.5	1.9
Vitamin B_{12} (μg/day)	1.2	2.1	4.1	8.1	14.1
Folate (μg/day)	142	197	276	366	478
Pantothenic acid (mg/day)	3.2	4.2	5.4	6.8	8.4
Vitamin C (mg/day)	26	46	81	132	193
Sodium (mg/day)	2154	2893	3782	4795	5871
Salt equivalent (g/day)	5.5	7.3	9.6	12.2	14.9
Potassium (mg/day)	1274	1680	2225	2869	3532
Calcium (mg/day)	212	307	448	637	832
Magnesium (mg/day)	144	187	241	308	380
Phosphorous (mg/day)	599	766	969	1216	1478
Iron (mg/day)	4.3	5.7	7.4	9.6	11.9
Zinc (mg/day)	4.9	6.2	7.9	9.9	12.4
Copper (mg/day)	0.7	0.9	1.1	1.4	1.7
Fruits (g/day)	0	0	55	157	272
Vegetables (g/day)	89	154	250	370	514

Table 1. The percentile values of energy, nutrient, vegetable, and fruit intakes among the Japanese adults who participated in the National Health and Nutrition Survey 2019 (n = 4927).

Individuals who do not meet 350 g vegetables and 100 g fruits intake		Individuals who do not meet 350 g vegetables intake		Individuals who do not meet 100 g fruits intake	
n	(%)	n	(%)	n	(%)
4222	(85.7)	3538	(71.8)	3033	(61.6)

Table 2. The proportion of individuals consuming less than 100 g of fruit and less than 350 g of vegetables, or failing to meet either criteria among Japanese adults who participated in the National Health and Nutrition Survey 2019 (n = 4927).

Table 3 shows the estimated intake of fibre, vitamin A, and potassium from fruits and vegetables based on nine scenarios of fruit intake and the estimated average intake of fruits and vegetables required to meet the DRIs in these scenarios using data from the NHNS 2019. The mean intakes of dietary fibre, vitamin A, and potassium from fruits were 1.4 g, 27 μgRAE, and 194 mg, respectively. From vegetables, the mean intake of dietary fibre, vitamin A, and potassium was also 5.4 g, 271 μgRAE, and 530 mg, respectively. In a scenario where more than 90% of adults consume 200 g of fruits per day, an average vegetable intake of approximately 350 g would almost meet the reference value of the DRIs for dietary fibre, vitamin A, except for potassium. In addition, the estimated average fruit intake under this scenario was approximately 200 g.

Discussion

This study evaluated fruit and vegetable intake that would result in meeting the DRIs for nutrients (dietary fibre and vitamin A, folate, vitamin C, and potassium), of which fruits and vegetables were the main sources, based on nine fruit intake scenarios using the current Japanese dietary patterns obtained from the NHNS 2019 results.

The scenario of the fruits intake	Nutrients	Reference value†	The amount of nutrients from vegetables	The amount of nutrients from fruits	Total intake	The estimated nutrient intake from fruits for the scenario‡	The amount of nutrients estimated to be insufficient to meet the reference values§	Vegetable intake that should be taken to meet the reference values (g)¶	The estimated average fruits intake (g)††
Over 70% of adults consume 100 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	1.7	1.9	381	124
	Vitamin A (μgRAE)	650	271	27	547	34	96	380	
	Potassium (mg)	3000	530	194	2350	242	601	599	
Over 80% of adults consume 100 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	1.8	1.8	374	133
	Vitamin A (μgRAE)	650	271	27	547	36	94	377	
	Potassium (mg)	3000	530	194	2350	260	584	589	
Over 90% of adults consume 100 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	1.9	1.7	369	140
	Vitamin A (μgRAE)	650	271	27	547	38	92	375	
	Potassium (mg)	3000	530	194	2350	273	571	583	
Over 70% of adults consume 150 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2	1.6	364	149
	Vitamin A (μgRAE)	650	271	27	547	41	89	373	
	Potassium (mg)	3000	530	194	2350	284	560	576	
Over 80% of adults consume 150 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2.2	1.4	353	160
	Vitamin A (μgRAE)	650	271	27	547	44	86	370	
	Potassium (mg)	3000	530	194	2350	305	539	566	
Over 90% of adults consume 150 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2.3	1.3	348	171
	Vitamin A (μgRAE)	650	271	27	547	47	83	366	
	Potassium (mg)	3000	530	194	2350	326	518	555	
Over 70% of adults consume 200 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2.4	1.2	343	177
	Vitamin A (μgRAE)	650	271	27	547	48	82	366	
	Potassium (mg)	3000	530	194	2350	335	509	550	
Over 80% of adults consume 200 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2.6	1	332	192
	Vitamin A (μgRAE)	650	271	27	547	52	78	361	
	Potassium (mg)	3000	530	194	2350	362	482	536	
Over 90% of adults consume 200 g/day	Dietary fibre (g)	21	5.4	1.4	18.8	2.8	0.8	322	207
	Vitamin A (μgRAE)	650	271	27	547	56	74	357	
	Potassium (mg)	3000	530	194	2350	389	455	521	

Table 3. The estimated average daily intake of dietary fibre and vitamin A, potassium according to the nine scenarios of fruit intake, and the average intake of vegetables and fruits required to meet the Dietary Reference Intakes in these scenarios using the data from the National Health and Nutrition Survey 2019. DG, tentative dietary goal for preventing lifestyle-related diseases; DRIs, Dietary Reference Intakes for Japanese; EAR, estimated average requirement; NHNS, National Health and Nutrition Survey in Japan. † Highest value among the reference values (DG for total fibre and potassium, and EAR for vitamin A) of adults for each nutrient in the Dietary Reference Intakes for Japanese. ‡ Nutrient intake from fruit of Japanese adults who participated in the NHNS when classified into two groups using the fruit intake set in the scenario as a cut-off. § The value obtained by subtracting the nutrient intake from non-fruit foods and the scenario-based nutrient intake from fruit among Japanese adults who participated in NHNS 2019 from the DRIs reference values. ¶ Vegetable intake required to meet the reference values during the vegetable intake patterns observed in the NHNS 2019. †† The estimated average intake of fruit when consumed in the scenario.

Although there have been previous reports on simulations of fruit and vegetable intake focusing on disease risk, to the best of our knowledge, this is the first study to simulate the ideal intake required to meet the DRIs values.

Fruits and vegetables are a source of a variety of nutrients, including phytochemicals, vitamins, minerals, and dietary fibre[20]. The intake of dietary fibre, vitamin A, folate, and vitamin C from fruits and vegetables constituted approximately 40–70% of the total intake among the participants in the NHNS 2019, which is the latest representative dietary intake data[13] of the Japanese population. Potassium intake from fruits and vegetables was approximately 30%, with grains, tubers, legumes, fishs, meats, dairy, beverages, and seasonings each accounting for approximately 10%. This distribution suggests that Japanese people consume potassium evenly from various sources. Dietary patterns among the Japanese have been reported to have diversified over the past 13 years[10], which may partly explain the high intake of potassium from a variety of food sources nowadays. Consequently, it is difficult to meet the value of the DRIs for potassium[14] by simply increasing the intake of fruits and vegetables in the current dietary pattern of Japanese adults; however, it may help to get closer to the value of the DRIs for potassium[14] by increasing the intake of fruits and vegetables.

Previous health promotions in Japan, such as Healthy Japan 21 and its second term, set targets to reduce the proportion of those consuming less than 100 g of fruits to 30% and consuming an average of 350 g of vegetables[8]. Globally, the recommended intake levels for vegetables are provided by 19 of the OECD member countries (30

countries), ranging from 160 to 540 g[21]. In contrast, nine countries have set combined recommendations for fruits and vegetables ranging from 400 to 850 g [21]. However, a few countries, including Japan, have achieved average intakes above these target levels of each country[20,22–24]. Thus, while increasing the intake of fruits and vegetables, which has been reported to reduce the risk of diseases such as CVDs and cancer[1], is a worldwide issue, differences in dietary patterns between countries make it necessary to consider food-based and diet-based target values, particularly when considering local food culture. In particular, the finding that Japanese people consume less fruit than Westerners[6] may mean that significant efforts are needed to increase fruit intake among Japanese people.

The results of our simulation indicated that the average intake of fruits and vegetables required to meet the reference values for dietary fibre and vitamin A was 200 g and 350 g, respectively. This is consistent with previous simulation studies on fruit and vegetable intake aimed at reducing the risk of diseases, such as heart disease and cancer, among Japanese individuals[11,12]. Furthermore, a meta-analysis integrating the results of studies from other countries suggested that consuming approximately five servings of fruits and vegetables, two servings of fruits or three servings of vegetables, per day was associated with the lowest mortality rates, with higher intakes not associated with further risk reduction[25]. This supports the results of this study, in which 200 g of fruits and 350 g of vegetables were required to meet the nutrient reference values to prevent nutrient intake deficiencies and lifestyle-related diseases.

To achieve the results of the current simulation (200 g of fruit and 350 g of vegetables), Japanese individuals must increase their intake to at least 100 g of fruit and 70 g of vegetables. Because there is a gap between the actual intake and target amounts of fruits and vegetables in many countries, the factors leading to increased intake are being explored, and intervention strategies are being tested on the basis of these factors. For example, social norm messages have been reported to increase the consumption of healthy foods, including fruits and vegetables[26], when used in promotions such as posters in the workplace (everyone in this canteen buys vegetable dishes)[27], and more recently, social media (following Instagram to encourage fruit and vegetable consumption)[28,29]. In addition, subsidy policies for fruits and vegetables have been implemented and reported to be cost-effective[30,31]. The umbrella review also suggests that intervention strategies implemented within homes, workplaces, mass media campaigns, household food production strategies, fiscal interventions, and primary care can be effective[32]. Such strategies should be considered to encourage improved fruit and vegetable intake in Japan. Furthermore, a strategy involving increased intake of vegetables (such as broccoli, carrots, spinach, and pumpkin) and fruits (such as apples and strawberries) rich in dietary fiber and vitamin A may help promote the achievement of goals.

This study has a few limitations. First, this simulation study was conducted according to the current dietary patterns in the Japanese population. The Japanese diet has been reported to change over time, and vegetable intake among Japanese people is likely to continue declining in the future[12]. Hence, our results should be interpreted with caution as this expected dietary change has not been considered. In addition, this simulation was the first attempt to compare the results with DRIs, and therefore, we adopted a theoretical approach of evaluating the adequacy of nutrients based solely on increases in fruit and vegetable intake. However, in real life, an increase in the intake of one food group tends to lead to changes in the intake of other food groups; thus, further consideration is needed in the future. Second, the dietary assessment used to estimate nutrient and food group intake in the NHNS was based on the one-day dietary record method excluding Sundays and public holidays[16]. Dietary record methods have been reported to underestimate intake by 15%[33], with vegetables and seasonings being the most commonly omitted foods[34]. Energy intake is over- or under-reported by approximately 10% of NHNS participants [35]; hence, the data used may not accurately reflect the intake of the target population. Additionally, it should be noted that the NHNS dietary survey is a one-day dietary survey and therefore does not represent habitual intake, and that the NCI method, which is used to estimate habitual intake (original data for multiple days or more is required to make an estimate) [36], cannot be applied. In addition, the exclusion of Sundays and holidays from dietary records can minimize variability due to a typical eating habits, but may limit the representativeness of usual intake patterns. Third, the nutrient intake of the NHNS participants was calculated based on the standard tables of food composition in Japan (STFCJ). However, new foods added to the market or changes to existing foods may not be fully reflected in the STFCJ. Fourth, the NHNS does not capture the intake of dietary supplements because there is no table of ingredients for dietary supplements in Japan. Therefore, it is possible that the nutrient intake of the Japanese population was overestimated or underestimated. Furthermore, Japanese people have been reported to consume more fruits in autumn[37]. As the NHNS was conducted in autumn (November)[16], it is difficult to follow this simulation, and further consideration may be needed to achieve 200 g of fruit intake per day throughout the year. Fifth, the participants in the NHNS were randomly selected from nationally representative households in Japan; however, the response rate was considered relatively Low (63.5%), and the individual-level response rate is unknown. These factors may have influenced the results of the simulation. Finally, the dietary data in the NHNS are obtained from a one-day dietary record. Since the range of intake is wider than that of habitual distribution, there is a possibility that the percentage of people who do not meet the EAR may be overestimated when compared with the EAR of DRIs. Therefore, caution is required when interpreting the results. Despite these limitations, a simulation analysis of fruit and vegetable intake using the NHNS, the only continuous nationally representative dietary data of the Japanese population, may inform future health and nutritional policies in Japan.

Conclusions

Based on nine scenarios, we predicted the amount of fruit and vegetable intake that would meet the DRIs for nutrients with fruits and vegetables as the main sources of intake. Our results indicated that 200 g of fruits and 350 g of vegetables, which have been reported to reduce the risk of disease, helped in meeting the DRIs values. As this fruit and vegetable intake is higher than the current Japanese intake, further research is needed

to examine policies and interventions that may promote an increase in fruit and vegetable intake among the Japanese population.

Data availability

This study was a secondary analysis of the 2019 National Health and Nutrition Survey in Japan and was conducted with the permission of the Ministry of Health, Labour and Welfare, in Japan. In addition, since the data was received after application to the Ministry of Health, Labor and Welfare and approval, there is no direct link to view the data but can be available from the corresponding author on reasonable request. All data generated or analysed during this study are included in this published article.

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Author contributions
All authors designed research. M.M. analyzed the data and wrote the first draft. E.O., X.Y., C.O., M.K. and M. N. took part in the interpretation of the data and provided critical revisions of the manuscript for important intellectual content. H.T. had primary responsibility for final content. All authors read and approved the final manuscript.

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