Factors associated with incidence of undernutrition in the elderly in evacuated areas after the Great East Japan Earthquake

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Abstract

Background: In order to extend healthy life expectancy, it is necessary not only to prevent illness but also to reduce frailty, defined as a decline in functioning across multiple physiological systems. To avoid vicious circles of frailty, it is important to detect undernutrition and decreased activity and to intervene early. Changes in the living environments of evacuees after the Great East Japan Earthquake have resulted in increased long-term care needs, with increasing stress and decreased physical activity. In addition, a certain number of elderly people have lost weight due to the disaster, and their nutritional intake has decreased, so the risk of frailty is expected to increase. However, the actual situation is not clear. This study aimed to ascertain the trends of undernutrition after the Great East Japan Earthquake and to examine longitudinally the relationship between lifestyle habits, including exercise habits, and the incidence of undernutrition.

Methods: This study included residents over the age of 60 who lived in the evacuation area municipalities from FY2008 to FY2010 prior to the disaster. We estimated the associations between undernutrition after the disaster and lifestyle factors using multivariable adjusted analysis by Cox proportional hazard regression analysis.

Results: In this study, 1,721 out of 13,378 subjects were newly undernourished. The incidence of undernutrition was associated with poor exercise habits / low physical activity, a history of surgery, a history of lifestyle-related diseases, two or more

subjective symptoms, meals before going to bed, and evacuation. No significant interaction with exercise habits was identified for each lifestyle factor.

Conclusion: These results suggest that it may be important to exercise regularly and/or maintain physical activity, regardless of sex, other lifestyle habits, or past medical history, to prevent undernutrition after a disaster.

Introduction

In Japan, with the advancing aging society, extending healthy life expectancy is a challenging issue. Many elderly adults (70% of men and 90% of women) have been reported to be less independent owing to delayed dysfunction caused by geriatric syndrome rather than illness.[1] To extend the healthy life expectancy of the elderly, it is necessary not only to prevent diseases but also to prevent and mitigate changes in aging owing to a decline in living functions. Elderly people tend to have low activity for various reasons, such as decreased appetite and nutrient intake, resulting in undernutrition and decreased muscle mass. Decreased muscle mass lowers not only the basal metabolism but also the limb muscle strength, which decreases the walking speed, ease of transfer, and activity. This is known as "the frailty cycle".[2] In Japan, the prevalence of undernutrition (Body Mass Index (BMI) $\leq$20.0 kg/m^2) in people over 80 years of age was reported to be more than 15% of men and more than 20% of women; this has become the main risk factor for health deterioration.[3] Early detection and early intervention of undernutrition and decrease in activity are very important to interrupt this vicious circle. The most common cause of long-term care among elderly people ($\geq$75 years of age) in Japan is weakness due to aging,[4] which is strongly associated with frailty. In frailty, the vulnerability to stress increases because of the decline in the physiological reserves, and subjects tend to live a dysfunctional life, depending on long-term care, or are at an increased risk of death.[5] Frailty is also an intermediate state

between healthy (robust) and disabled and is defined as a high risk of being dependent on long-term care, but can be restored to normal health with appropriate intervention.[6] In addition, frailty is a multifaceted concept; it not only involves physical problems, such as loss of muscular agility, that makes it easy to fall but also mental and psychological problems, such as cognitive impairment and depression, and includes social issues such as living alone and economic difficulties.[6-10] Physical frailty is evaluated according to five items by the Cardiovascular Health Study (CHS) criteria: weight loss, subjective fatigue, decreased daily life activity, decreased physical ability, and decreased muscle strength.[11] Of these, three or more items are defined as frailty when applied, and one or two items are defined as pre-frailty when applied.

After the Great East Japan Earthquake, many evacuees from the government-designated evacuation areas were forced to move and change their lifestyle behaviors, including diet, exercise, and other personal habits. Many evacuees had to change their jobs, and some of these people did not receive adequate health checks and had anxiety about their health to varying degrees. Such changes in the living environment following the disaster have resulted in increased psychological stress and decreased physical activity.[12-16] According the Fukushima Health Management Survey (FHMS), conducted in the Fukushima Prefecture after the disaster, lifestyle-related diseases have been confirmed to worsen with increasing body weight.[17-22] On the other hand, a certain number of residents have lost weight and reduced their nutrition intake due to the

disaster. The FHMS reported that people who evacuated to evacuation centers, temporary housing, apartments, etc., consumed less fruit and vegetables, meat, soy products, and dairy products than those who lived in their own or relative's homes.[23] These findings suggest that the risk of frailty is expected to increase in the elderly evacuees owing to aging, reduced physical activity, decreased nutrient intake, and changes in the living environment.[24]

In the Fukushima Prefecture, the aging rate after the disaster exceeded 30%, and the certification rate for long-term care also increased rapidly.[25, 26] In disaster-stricken municipalities, the number of certified long-term care insurance recipients and benefit costs after the disaster increased significantly. The rate of certification for long-term care also increased significantly; that of the evacuation area increased by 2.4%, while the prefecture average increased by 1.6%. In the evacuation area, aging was further accelerated after the disaster.[25] Therefore, frailty issues must be urgently addressed, and effective preventive measures need to be implemented. Overseas, the prevalence of frailty is approximately 7–10%[27] and, in people over the age of 75, the prevalence is 20–30%.[28] In Japan, the frequency of frailty (average age: 71 years) was reported to be 11.3% using CHS criteria.[29] In the results of the analysis that integrated four representative large-scale cohort studies using the CHS criteria in Japan, the prevalence of frailty in the community-dwelling elderly population was 7.4%. The prevalence of frailty increases with age, and rises markedly after the age of 75.[30]

Frailty is the leading cause of need for long-term care, and the Fukushima Prefecture's certification rate for requiring long-term care increased after the Great East Japan Earthquake. Frailty has also been reported to be affected by the damage caused by the disaster.[24] Therefore, it is necessary to check the actual situation of evacuation areas and examine the factors that lead to prevention. However, no study has shown the frequency of frailty among Fukushima residents, the actual state of weight loss or functional decline, or the relationship between the changes in the lifestyle owing to evacuation after the disaster and the risk of frailty. Furthermore, because there are no easy ways to evaluate frailty, a simple screening method for frailty is required.

From these perspectives, the purpose of this study was to clarify the relationship between the incidence of undernutrition after a disaster and lifestyle before the disaster. We performed a longitudinal study to investigate the factors associated with the incidence of undernutrition among elderly evacuees after a disaster. First, we examined the trends of undernutrition as one of the components of frailty before and after the Great East Japan Earthquake in elderly residents in the evacuated areas after the disaster. Next, we examined the relationship between the incidence of undernutrition and lifestyle factors, including physical exercise and dietary behavior. We hypothesized that people who maintained physical activity before the disaster would have a lower risk of undernutrition after the disaster. Clarifying the factors related to weight loss will help to reduce the risk of frailty in elderly evacuees after any disaster, and our findings may

provide useful information on how dependence on long-term care in the late phase of life can be reduced and how healthy life expectancy can be increased.

Methods

Rather than setting up a new screening site, we considered a method for screening frailty from related items using data from health examinations, a health project in which many local residents had already participated.

Study population

The subjects were residents ≥60 years of age who lived in evacuation-designated areas near the Fukushima Daiichi Nuclear Power Plant in the Fukushima Prefecture before the disaster. The evacuation area included 13 municipalities: Hirono-machi, Naraha-machi, Tomioka-machi, Kawauchi-mura, Okuma-machi, Futaba-machi, Namie-machi, Katsurao-mura, Iitate-mura, Kawamata-machi, Tamura City, Minami-Soma City, and Date City. Within the evacuation area, people aged 40–74 years had enrolled in national health insurance and people aged ≥75 years had enrolled in the medical system for the elderly and underwent annual health check-ups.

Table 1 shows the number of participants (total men and women) in each fiscal year from 2008 to 2017, and Figure 1 shows the age composition ratio by sex. Between 2008 and 2017, a total of 254,161 people aged ≥60 years received medical examinations. Of these, a total of 68,010 examinees aged ≥60 years old who underwent at least one health check-up before the disaster during 2008–2010 (the "baseline" period) were examined. We excluded the second and subsequent results if more than one visit was made during this period. Therefore, this study included

31,379 subjects (14,333 men and 17,046 women, average age: 69.7 years) who had a medical examination during this period.

We excluded 13,789 participants who were overweight (BMI≥ 25.0 kg/m^2) or undernourished (BMI≤ 20.0 kg/m^2); 17,601 subjects were eligible for follow-up. Follow-up examinations were conducted from 2011 to 2017. Because 4,223 participants did not undergo the follow-up examination, 13,378 participants (6,351 men and 7,027 women) were finally eligible for our analyses (Figure. 2).

Measurements/definitions and data collection

The data of the baseline (before the disaster) was provided by the medical examinations conducted by municipalities, such as specific medical examinations and late-elderly medical examinations. For follow-up (after the disaster) data, we used the FHMS data in addition to the above data conducted by municipalities. The baseline and follow-up examinations included a review of the medical history, physical examination, anthropometric measurements, and a questionnaire regarding lifestyle behaviors.

Definition of undernutrition

Body weights and heights were provided with shoes and excess clothing removed on the same calibrated scale at the baseline and follow-up. BMI was calculated as the body weight (kg) divided by the square of the height (m^2). According to the National Health and Nutrition Survey, undernutrition was defined by a BMI ≤20.0 kg/m^2. There

are some discussions about using BMI as an objective indicator in the elderly. BMI is not a sensitive indicator in a clinical setting to allow for rigorous changes in clinical situations, since even a person with normal or high BMI can have clinically significant weight loss. Alternatively, elderly people often have difficulty standing and/or spinal deformity, so the height measurement needed to calculate BMI is unreliable.[31] However, in this study, the target person is an elderly people who can undergo a health check-up living in the community, and some studies use BMI measured from health check-up as an indicator of undernutrition,[32] so we used this definition in here.

Amount of weight loss

The criterion for weight loss used for determining frailty is "2 to 3 kg in 6 months".[6, 11] In addition, as an “unintended sudden weight loss” for judging the risk of geriatric syndrome or the like, there is also an index of “5% weight loss in 6 to 12 months”. [33] However, it is difficult to identify the amount of weight loss in a short period of time from the tracking of the medical examination data used in this case. For this reason, in this study, the amount of change and the rate of change throughout the observation period were calculated as follows. “Weight loss (≥5 kg or ≥5%)” from the baseline, “weight loss (kg)”, “weight loss per year (kg/year)”, “weight loss rate (loss/weight)”, and “weight loss rate per year (%/year)” were calculated.

Lifestyle status

Information on lifestyle factors, such as smoking status, exercise habits, physical

activities, insufficient sleep, and dietary behaviors, were obtained by a self-administered questionnaire from the standard interview items during medical check-ups[34] and classified into two categories. Smoking status was indicated by smoking regularly or not. Insufficient sleep was defined by whether sleep provided rest (yes/no). Dietary behaviors were defined as follows: skips breakfast (skipping breakfast more than three times a week), meals before going to bed (having dinner within 2 h before going to bed at least three times a week), and snacking after dinner (more than three snacks after dinner a week). Drinking status was indicated by the frequency of drinking and the amount of alcohol consumed per day and was categorized into three groups from the weekly alcohol intake: "Never drink (including quitting)," "Drink less than 44 g/day," and "Drink more than 44 g/day". Other items in the standard interview were as follows: weight gain of over 10 kg since the age of 20 years (yes/no), increase/decrease of body weight over 3 kg in one year (yes/no), and walking speed (faster walking speed compared to same age of same sex; yes/no).

Exercise habits and physical activities

The "Physical Activity Standards for Health Promotion 2013" distinguishes between "exercise habits" for the purpose of sports and physical fitness, and "physical activities" related to living, such as employment, housework, and mobility.[35] The questionnaire items for medical examination are set according to this, and in this study are also defined as follows: exercise habit was defined by

whether they were lightly sweating and exercising for at least 30 minutes at least twice a week for over one year. Physical activity was defined by walking for 1 hour or more per day or equivalent activity.

Medical history

Information on medical history, surgery, and subjective symptoms was provided through interviews with local public health nurses. A history of digestive surgery was defined as having at least one occurrence of esophageal, stomach, duodenal, or colon surgery. A history of lifestyle-related disease was defined as having a history of any one of the following: hypertension, dyslipidemia, diabetes, hepatic dysfunction, or renal dysfunction. Subjective symptoms were classified into three categories: none, one, or two or more, out of eight physical symptoms in the past year.

Evacuees

In this study, since there was no information about the evacuation status of individuals based on the target person's residence area in the target municipalities, all residents in areas designated as evacuation areas were defined as evacuees, and those in areas not designated as evacuation areas were defined as non-evacuees.

Statistical analysis

First, the changes in the number of population with undernutrition tendency for 10

years were confirmed by sex and age group, and we analyzed trends in the prevalence of undernutrition by sex, in the 10-year period from 2008 to 2017, using a joinpoint regression model. Next, the participants were divided into two groups: undernourished (n = 1,712) and not undernourished (n = 13,019). Participants with and without undernutrition were compared using the χ^2 test and Fisher's exact test for categorical variables and *t*-test for continuous variables. We tested the associations between undernutrition after the accident and other primary lifestyle factors using simple, sex-age-adjusted, and multivariable-adjusted analysis by Cox proportional hazard regression analysis. Although there were missing values for lifestyle factors, there was no difference in average age, average BMI, and the proportion of gender, malnutrition, evacuation, exercise habits, physical activity, etc. even if the missing values were excluded. So they were treated as missing to ensure representativeness. In univariate analysis, analysis was performed after deleting missing data, and in the multivariable analysis, adjustments were made by inserting dummy variables into the missing data. In the multivariable-adjustment model, items that were significantly associated with the sex-age-adjustment model were used as adjustment variables. To avoid multicollinearity of exercise habits and physical activity, only one of them was used as an adjustment variable if both were significant in a sex-age-adjusted analysis. The follow-up period was defined as the period until the first time undernutrition was determined in cases with undernutrition and, in cases without undernutrition, the follow-up period was

defined as the period until the last medical examination in 2017. Person-years were calculated as the sum of the individual follow-up times until the incidence of undernutrition or the last time of examination.

SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for all statistical analyses. Probability values for the statistical tests were two-tailed, and a p value of $\leq$0.05 was considered statistically significant.

Ethical considerations

The Ethics Committee of the Fukushima Medical University approved this study (#1319, 1916). Informed consent was obtained from community representatives to conduct an epidemiologic study based on the guidelines of the Council for International Organizations of Medical Science.

Results

Trends in undernutrition before and after the disaster

The prevalence of undernutrition in people ≥ 60 years was tabulated and the changes were examined by sex and overall in each year from 2008 to 2017. The trends in the prevalence of undernutrition are shown in Figure 3, and the trends stratified by sex and age composition are shown in Figure 4. The prevalence of undernutrition decreased once at FY2011. The prevalence of men subjects with undernutrition slightly increased for several years after the disaster, and was almost flat in the last three years, but did not return to the original state before the disaster. However, in women, the prevalence of undernourished subjects gradually increased after the disaster, and the prevalence of undernutrition in the last three years was the same or higher than before the disaster. Figure 5 shows that Annual Percent Change (APC) of men and women, that was -3.28 and was 1.40 respectively, and both of the APC is significantly different from zero at the alpha=0.05 revel. As a result, no significant inflection point was found in both men and women, and it was found that men gradually decreased and women gradually increased. In addition, when comparing the trend of subjects of ≥65 years of age with the national data[3] from the 2017 National Health and Nutrition Survey, the prevalence of undernutrition in both men and women tended to be lower than that reported in the national data (Figure 6).

Relationship between lifestyle factors and undernutrition after the disaster

Frequency and characteristics of undernutrition after the disaster

The baseline characteristics of the study participants with and without undernutrition are shown in Table 2. The rate of follow-up participants was 76.0% (13,378/17,601 participants). The mean age of the participants was 68.4 ±6.2 years, and 46.6% were men. During the 6.9 year follow up, 1,712 participants (12.8%) were found to be undernourished. The undernourished participants were significantly older with a higher percentage of women and a lower percentage of evacuees. Compared with the participants without undernutrition, the frequency of meals before going to bed, exercise habits, physical activity, smoking habits, and alcohol consumption were lower among those with undernutrition. In addition, the proportion of lifestyle-related diseases was significantly higher among the participants with undernutrition compared to that among the participants without undernutrition.

Lifestyle factors associated with the incidence of undernutrition

Table 3 shows the sex-age-adjusted and multivariable-adjusted hazard ratios (HRs) and 95% confidence intervals (95% CIs) of each lifestyle factor of the incidence of undernutrition. The multivariable-adjusted model included the following variables that were significantly associated with the sex-age-adjustment model; age, sex, evacuation (yes/no), smoking status (yes/no), drinking status (never, <44g/day, ≥44g/day), exercise habit (enough/poor), physical activity (enough/poor), meals before going to bed (≥3

times a week/<3 times a week), history of digestive surgery (yes/no), history of lifestyle-related disease (yes/no), and subjective symptoms (nothing, 1 symptom, 2 or more symptoms). Exercise habits and physical activity were related to each other in the χ^2 test (chi-square value 2538.43, p-value <0.0001, phi coefficient 0.45). Therefore, to avoid multicollinearity, if both were significant in the sex-age-adjustment analysis, only one of them was used as an adjustment variable. The significant variables influencing the incidence of undernutrition in model 1 were as follows: evacuation (HR = 1.31 95% CI: 1.17–1.47), inadequate (poor) exercise habits (HR = 1.14, 95% CI: 1.03–1.27), no or infrequent meals before going to bed (HR = 1.26, 95% CI: 1.11–1.43), a history of digestive surgery (HR = 1.24, 95% CI: 1.03–1.50), a history of lifestyle-related disease (HR = 1.27, 95% CI: 1.16–1.40), and two or more subjective symptoms (HR = 1.26, 95% CI: 1.04–1.53). Incidentally, the HR (95%CI) of the exercise habits was essentially unchanged, even when baseline levels of BMI was added to the adjustment variable.

Those significant variables influencing the incidence of undernutrition in model 2 were as follows: evacuation (HR = 1.31, 95% CI: 1.17-1.47), inadequate (poor) physical activity (HR = 1.14, 95% CI: 1.01–1.25), no or infrequent meals before going to bed (HR = 1.25, 95% CI: 1.01–1.42), a history of digestive surgery (HR = 1.24, 95% CI: 1.02–1.49), a history of lifestyle-related disease (HR = 1.28, 95% CI: 1.16–1.41), and two or more subjective symptoms (HR = 1.26, 95% CI: 1.04–1.52). Incidentally, the HR of physical activity (95%CI) was not significant when baseline levels of BMI was added

to the adjustment variable.

Table 4 shows the HRs of the exercise habits or physical activity to incidence of undernutrition after the disaster respectively, in a multivariable-adjustment model, stratified by each lifestyle factor. This model was adjusted for age, sex, evacuation, smoking status, drinking status, meals before going to bed, exercise habits or physical activity, digestive surgery, lifestyle-related diseases, and subjective symptoms. From the results of the multivariable-adjusted analysis model stratified by each lifestyle factor, no significant interaction with exercise habits or physical activity was confirmed in each lifestyle factor.

Discussion

Trends in undernutrition before and after the disaster

The prevalence of undernutrition in the elderly aged ≥60 in the evacuated areas decreased just after the disaster. However, after the disaster, the prevalence of undernutrition in men remained lower than before the disaster. In women, the prevalence of undernutrition continued to increase gradually after the disaster. According to the FHMS, after the disaster, both the mean body weight and the proportion of overweight/obese people increased significantly, especially among men, for both evacuees and non-evacuees. It has been confirmed that the risk of lifestyle-related illnesses has worsened with weight gain following a disaster. Furthermore, evacuation is significantly associated with an increased risk of becoming overweight/obese.[17] Therefore, the effect of weight gain is significant and that of weight loss may be offset. On the other hand, in the fiscal year 2011 (immediately after the disaster), the number of target persons immediately increased, because the data of the FHMS included subjects other than specific medical examinations and late-elderly medical examinations. This may have modified the results for fiscal year 2011.

In addition, when comparing the trend of ≥65 years of age with the national data of the 2017 National Health and Nutrition Survey,[3] the prevalence of undernutrition tended to be lower than that reported in the national data. Because it is possible that a person who is undernourished has not undergone a medical checkup, it is necessary to

investigate whether this result, which includes the target population, is characteristic of the evacuation area, and to compare it with the results of other areas outside the evacuation area in the Fukushima Prefecture.

The three major causes of weight loss are malignant tumors such as cancer, gastrointestinal diseases such as gastric/duodenal ulcer, inflammatory bowel disease, chronic pancreatitis, and mental illnesses such as depression, dementia, alcoholism, and eating disorders.[33] In our study, a history of digestive surgery and lifestyle-related diseases affected the incidence of undernutrition after the disaster. Needless to say, to prevent undernutrition, it is important to prevent these diseases.

Effects of exercise habits and physical activities

The multivariable analysis in this study showed that exercise habits and physical activities affected the incidence of undernutrition after the disaster in elderly people. The HR of the exercise habits was essentially unchanged even when the baseline levels of BMI were added to the adjustment variable. Therefore, exercise habits are an important preventive factor for undernutrition among elderly men and women regardless of whether the baseline weight is high or low. In addition, from the results of the stratification by the main adjustment variables of the same multivariable analysis, no interaction with exercise habits was confirmed for any variables. Thus, it is important for elderly people in evacuated areas to maintain their exercise habits and physical

activities, regardless of their sex, age, drinking and smoking status, and medical history, to prevent the incidence of undernutrition after a disaster.

Increasing the amount of daily physical activity can reduce the risk of age-related declines in life functions, such as decreased motor function and dementia. In particular, elderly people can live longer independently by promoting physical activity.[35] Several prospective cohort studies among Japanese subjects have shown that more physical activity and exercise can lower the risk of developing lifestyle-related diseases, some cancers, and death.[36-38] Furthermore, exercise habits are associated with improving the quality of life of elderly people,[39] and decreasing the risk of an upper respiratory tract infection.[40] In this study, because we did not examine changes in exercise habits and physical activity after the disaster, we cannot mention the effects of exercise habits and physical activity on the incidence of undernutrition. On the other hand, the results of this study reveal that, regardless exercise habits after the disaster, having good exercise habits before the disaster suppressed the incidence of undernutrition after the disaster. Maintaining exercise habits and physical activity in daily life is important for elderly people, who are more vulnerable to disaster and more easily influenced by disasters, to reduce the risk of loss of physical function and to improve quality of life. Frailty can be treated using an intervention program, such as improving walking speed or amount of physical activity.[41]

Association with evacuation

In this study, the prevalence of undernutrition was low among the evacuees after the disaster. According to the FHMS, after the disaster, large percentages of people in the evacuation areas gained weight.[17] The results of this study indicate that, in the evacuation areas, even older people gained weight. However, a certain number of people in the evacuation areas were found to be undernourished. After the Great East Japan Earthquake, life in shelters was prolonged. The meals there were high in carbohydrates.[14] In addition, living in non-house conditions after the Great East Japan Earthquake was associated with poor dietary intake of fruits and vegetables, meat, soybean products, and daily products.[23] There are also reports that energy and protein became excessive.[16] In this way, in an environment where the contents and form of meals could not be selected, and evacuees are forced to eat the food available, regardless of its nutritional balance, it was thought that evacuees, as a whole, would gain weight. However, for elderly people with poor digestive or swallowing/chewing function, nutritional intake may decrease in these circumstances. The problem is that evacuation areas tend to focus on gaining weight only and tend to delay their response to undernutrition. In situations such as disasters, it is important not to miss these cases.

Association with late meals

In this study, the tendency to eat meals before going to bed less than three times a

week was a risk of incidence of undernutrition. Eating within two hours of bedtime is regarded as a dietary habit that promotes obesity. This is due to the accumulation of fat due to insulin secretion and the action of the appetite hormone leptin. On the other hand, elderly people have a higher risk of undernutrition and/or weight loss compared with younger people. Therefore, delaying dinner may be able to prevent undernutrition and weight loss. Conversely, avoiding or skipping dinner because of too late can promote undernutrition and result in weight loss. However, going to bed immediately after a meal is not recommended for long-term habits, as it degrades sleep quality and strains the gastrointestinal tract. Rather than recommending late time meals, it is important to review the dietary balance and lifestyle.

Importance of early detection and intervention for frailty

Frailty is a term that was advocated in 2014.[6] However, in Japan, the care prevention business started in 2006, and support and countermeasures have been implemented since then. Elderly people who are frail were subject to support and secondary prevention measures under the former system. Whether frailty improves or worsens not only impairs independence and quality of life, but also has important social implications, including increased social security expenditures such as health care and long-term care benefits. It has been shown that exercise intervention for disability in daily life activities has the effect of improving frailty. In addition, the improvement

effect by muscle training was found to be effective for mild to moderate frailty but not for severe frailty.[43] It is therefore important to intervene in the early stages of frailty.[44]

Problems in conducting screening for more subjects

There are several challenges in screening large numbers of subjects for frailty. Screening tests for elderly people are performed at clinics or during health check-ups, and they are usually performed in geriatric clubs and salons. Moreover, there is also a method known as “postal inspection”. Many elderly people with frailty have been reported to have some kind of disease; in these cases, it is necessary to have a cooperative relationship with the medical association and the local government, and it is important to create a mechanism for cooperation.[45] In addition, it is difficult to follow-up with many elderly people because there is a barrier to participation in the implementation at salons. For early detection, a simple and easy screening method that can be performed in a situation where more people gather is desired, such as the medical examination used in this study.

Limitations of this study

First, because high-risk persons with undernutrition might tend to receive medical treatment, they are less likely to undergo health check-ups, and the possibility of a selection bias cannot be denied. Comparing the characteristics of the 13,378 subjects

analyzed in this study with those of the 4,223 people who could not be tracked, the age groups were significantly different, with an average age of 68.4 years versus 73.3 years, respectively, although there was no difference in percentage of men, exercise habits, or physical activity. Second, the incidence of undernutrition in some cases was due to other diseases (other than lifestyle), although they could not be excluded by analysis. This may have modified the results. Third, this study used items from health check-ups, so there is a lack of detailed information on nutrient intake, which is strongly associated with weight loss and incidence of undernutrition. Fourth, the estimated weight loss, which is a risk factor for elderly people, is 3–5 kg or 5% reduction of body weight over the past 6 months to 1 year[33]; however, in this study, the follow-up period varied for the participants, which makes it difficult to determine when weight loss had occurred. Finally, in this study, we examined the effects of exercise habits before the disaster (baseline), but did not examine changes in exercise habits after the disaster. Therefore, it could not be determined whether the continuation of exercise habits affected the incidence of undernutrition.

Future prospects

Frailty has multifaceted components, and undernutrition in the elderly is affected not only by medical history and lifestyle habits, but also by social psychological factors, such as family morphology, connection with the community, and depressed mood.[33] In

this study, only data from the results of medical examinations were examined but, in order to examine how lifestyle and social psychological factors are related to the incidence of undernutrition after any disaster, we need to examine the mental health and lifestyle surveys conducted by the FHNS on residents in the same evacuation area. In addition, to determine whether the results obtained are a peculiar phenomenon caused by a disaster (for example, evacuation life), they need to be compared with current information and medical examination data outside the evacuation area.

Conclusion and implications

We examined the trends of undernutrition among elderly people in evacuation areas in the Fukushima Prefecture during the 10 years before and after the Great East Japan Earthquake. It was found that undernutrition in men has been on a declining trend since the disaster, whilst undernutrition in women has been on a rising trend. In addition, we examined the associations between the incidence of undernutrition and related lifestyle factors using health checkup data for residents ≥60 years of age who lived in evacuation areas before the disaster. The findings of our study suggest that, in order to prevent the incidence of undernutrition after any disaster, individuals need to maintain their exercise habits and physical activities appropriately, regardless of sex or other lifestyle habits.

Acknowledgments

We thank the expert committee members, advisors, staff of the Fukushima Health Survey Group, and municipalities in evacuation area for conducting this survey and for their support. This work was supported by the National Health Fund for Children and Adults Affected by the Nuclear Incident. The findings and conclusions of this article are solely the responsibility of the authors and do not represent the official views of the Fukushima Prefectural Government. All authors participated in study conception and design. T. Ohira, and K. Okazaki performed statistical analysis of the data. All authors participated in interpretation of the results and drafting of the manuscript, and they approved the final version.

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Table 1. The number of participants in each fiscal year

fiscal year	Total	men	women
2008	22,626	10,204	12,422
2009	22,815	10,496	12,319
2010	22,569	10,410	12,158
2011	29,973	13,775	16,198
2012	24,921	11,706	13,215
2013	25,690	11,964	13,726
2014	26,394	12,145	14,249
2015	25,020	11,094	13,926
2016	27,104	12,431	14,673
2017	27,049	12,467	14,582

Table2. Characteristics at baseline of 13,378 participants with and without incident of undernutrition

Participants		n	Total 13,378	Undernutrition 1,712 (12.8)	non-Undernutrition 11,666 (87.2)	p values*
Follow-up period, (years)		13,378	6.9 (2.2)	4.9 (2.0)	7.2 (2.1)	<0.001
Evacuee, (%)		13,378	3,732 (27.9)	411 (24.0)	3,321 (28.5)	<0.001
Sex(men), n(%)		13,378	6,351 (47.5)	631 (36.9)	5,720 (51.0)	<0.001
Age, (years)		13,378	68.4 (6.2)	68.8 (6.3)	68.3 (6.2)	0.003
75 years old or older, n(%)		13,378	2,796 (20.9)	389 (22.7)	2,407 (20.6)	0.047
80 years old or older, n(%)		13,378	659 (4.9)	99 (5.8)	560 (4.8)	0.08
Body weight, (kg)		13,378	54.7 (6.8)	50.7 (6.0)	55.2 (6.7)	<0.001
Body mass index, (kg/m^2)		13,378	22.7 (1.3)	21.3 (1.0)	22.9 (1.3)	<0.001
Amount of Weight loss, (kg)		13,378	0.53 (3.8)	4.65 (3.0)	-0.07 (3.5)	<0.001
Rate of Weight loss, (%)		13,378	1.01 (7.0)	9.02 (5.4)	-0.16 (6.4)	<0.001
Rate of Weight loss, (kg/year)		13,378	0.12 (0.7)	1.05 (0.8)	-0.02 (0.6)	<0.001
Rate of Weight loss, (%/year)		13,378	0.22 (1.4)	2.06 (1.6)	-0.05 (1.1)	<0.001
Weight loss ≥ 5kg, n(%)		13,378	1,422 (10.6)	645 (37.7)	777 (6.7)	<0.001
Weight loss ≥ 5%, n(%)		13,378	3,560 (26.6)	1,268 (74.1)	2,292 (19.7)	<0.001
Exercise habits, n(%)	poor	12,488	8,061 (64.6)	1,065 (67.0)	6,996 (64.2)	0.03
Physical activities, n(%)	poor	12,495	7,556 (60.5)	1,010 (63.5)	6,546 (60.0)	0.008
Walking speed, n(%)	fast	12,490	5,543 (44.4)	693 (43.6)	4,850 (44.5)	0.51
Insufficient sleep, n(%)	yes	12,532	9,768 (77.9)	1,212 (76.1)	8,556 (78.2)	0.06
Weight change from age 20, n(%)	≥ 10 kg	12,493	2,760 (22.1)	161 (10.1)	2,599 (23.8)	<0.001
Weight change in 1year, n(%)	≥ ±3 kg	12,492	2,055 (16.5)	201 (12.7)	1,854 (17.0)	<0.001
Meals before going to bed, n(%)	≥ 3 times/week	12,498	2,835 (22.7)	294 (18.5)	2,541 (23.3)	<0.001
Snack after dinner, n(%)	≥ 3 times/week	12,514	913 (7.3)	116 (7.3)	797 (7.3)	0.98
Lack of breakfast,n(%)	≥ 3 times/week	12,502	445 (3.6)	60 (3.8)	385 (3.5)	0.61
Smoking status, n(%)	Current smoker	13,378	1,762 (13.2)	194 (11.3)	1,568 (13.4)	0.02
Drinking status, n(%)	Non drinker	13,378	7,553 (56.5)	1,098 (64.1)	6,455 (55.3)	<0.001
	Current drinker, < 44g/day		5,164 (38.6)	547 (32.0)	4,617 (39.6)	
	Current drinker, ≥ 44g/day		661 (4.9)	67 (3.9)	594 (5.1)	
Digestive surgery, n(%)	yes	13,378	821 (6.1)	120 (7.0)	701 (6.0)	0.11
Lifestyle-related diseases, n(%)	yes	13,378	5,586 (41.8)	797 (46.6)	4,789 (41.1)	<0.001
Subjective symptoms, n(%)	nothing	13,378	10,543 (78.8)	1,339 (78.2)	9,204 (78.9)	0.04
	1 symptom		2,077 (15.5)	254 (14.8)	1,823 (15.6)	
	2 or more		758 (5.7)	119 (7.0)	639 (5.5)	

undernutrition;BMI≤20.0kg/m^2, non-undernutrition;BMI>20.0kg/m^2.

Value expressed as mean (standard deviation) or number of people (proportion).

* For categorical variables, we used the χ^2 test and Fisher's exact test, and for continuous variables, we used the t test.

Table3. Hazard ratios (95% confidence intervals) of incidence of undernutrition after the disaster of lifestyle factors among 13,378 participants

		Sex- Age- adjustment			Multivariable adjustment (Model1)*			Multivariable adjustment (Model2)**		
Factor		HR (95% CI)		p values	HR (95% CI)		p values	HR (95% CI)		p values
Sex	women	1.63	(1.48- 1.80)	<0.001	1.64	(1.45- 1.85)	<0.001	1.63	(1.44- 1.84)	<0.001
Age	1SD (6.2 years)	1.24	(1.18- 1.31)	<0.001	1.25	(1.18- 1.32)	<0.001	1.24	(1.18- 1.31)	<0.001
	≥ 75 years old	1.60	(1.43- 1.79)	<0.001						
	≥ 80 years old	1.96	(1.60- 2.41)	<0.001						
Evacuation	no	1.36	(1.21- 1.52)	<0.001	1.31	(1.17- 1.47)	<0.001	1.31	(1.17- 1.47)	<0.001
Walking speed	fast	0.94	(0.85- 1.03)	0.18						
Insufficient sleep	yes	1.11	(0.99- 1.25)	0.08						
Exercise habits	poor	1.16	(1.04- 1.29)	0.006	1.14	(1.03- 1.27)	0.02			
Physical activities	poor	1.15	(1.04- 1.27)	0.009				1.12	(1.01- 1.25)	0.03
Smoking status	yes	1.20	(1.02- 1.41)	0.03	1.16	(0.99- 1.37)	0.07	1.16	(0.99- 1.37)	0.07
Drinking status	< 44g/day	0.87	(0.77- 0.97)	0.02	0.89	(0.79- 1.00)	0.05	0.89	(0.79- 1.00)	0.04
	≥ 44g/day	1.03	(0.79- 1.34)	0.86	1.07	(0.82- 1.39)	0.64	1.06	(0.81- 1.39)	0.66
Meals before going to bed	< 3times/week	1.27	(1.12- 1.44)	<0.001	1.26	(1.11- 1.43)	0.03	1.25	(1.10- 1.42)	<0.001
Snack after dinner	≥ 3 time/week	1.01	(0.84- 1.22)	0.90						
Digestive surgery	yes	1.27	(1.05- 1.53)	0.01	1.24	(1.03- 1.50)	0.02	1.24	(1.02- 1.49)	0.03
Lifestyle-related diseases	yes	1.29	(1.17- 1.42)	<0.001	1.27	(1.16- 1.40)	<0.001	1.28	(1.16- 1.41)	<0.001
Subjective symptoms	1 symptom	0.96	(0.84- 1.10)	0.54	0.98	(0.86- 1.13)	0.80	0.98	(0.86- 1.13)	0.80
	2 or more	1.25	(1.04- 1.51)	0.02	1.26	(1.04- 1.53)	0.02	1.26	(1.04- 1.52)	0.02

HR; Hazard ratio. CI; confidence interval. SD; standard deviation

Dependent variable:Undernutrition. Independent variable of interest: Exercise habits or Phisical activity.

* Model1 : Adjustment variables included in the model: Age, Sex, Evacuation, Exercise habits, Smoking status, Drinking status, Meals before going to bed, Digestive surgery, Lifestyle-related diseases, and Subjective symptoms.

** Model2 : Adjustment variables included in the model:Age, Sex, Evacuation, Physical activity, Smoking status, Drinking status, Meals before going to bed, Digestive surgery, Lifestyle-related diseases, and Subjective symptoms.

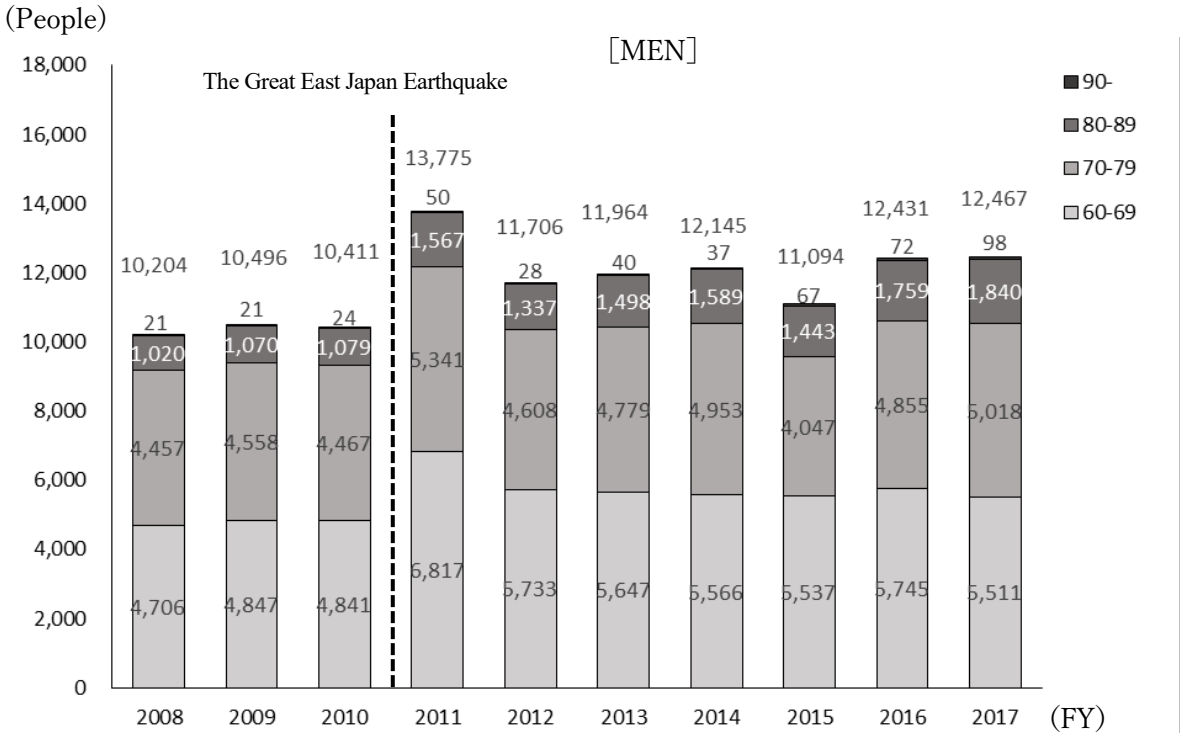
Table4. Hazard ratios (95% confidence intervals) of exercise habits for incidence of undernutrition after disaster among 13,378 stratified by each lifestyle factor

Factor		Exercise habit	poor Exercise habit				Physical activity	poor Physical activity			
		4,427	8,061				4,939	7,556			
Number of undernutrition		525	1,065				580	1,010			
follow-up years		7.09	6.98				7.02	7.01			
Total person-years		31,381	56,249				34,678	53,004			
Incidence rate of undernutrition (1,000 person-years)		16.7	18.9				16.7	19.1			
			HR (95%CI)			p values*1	p for interaction	HR (95%CI)			p values*2	p for interaction
Sex	men	Reference	1.21	(1.02- 1.44)	0.03	0.49	Reference	1.08	(0.92- 1.28)	0.34	0.39
	women	Reference	1.10	(0.96- 1.25)	0.18		Reference	1.15	(1.01- 1.31)	0.04	
Age group	≥75years old	Reference	0.93	(0.73- 1.19)	0.56	0.54	Reference	1.00	(0.78- 1.27)	0.97	0.44
	<75years old	Reference	1.18	(1.05- 1.33)	0.005		Reference	1.15	(1.02- 1.29)	0.02	
Evacuation	no	Reference	1.19	(1.05- 1.35)	0.007	0.26	Reference	1.10	(0.97- 1.24)	0.13	0.40
	yes	Reference	1.02	(0.85- 1.24)	0.81		Reference	1.18	(0.98- 1.43)	0.09	
Smoking status	no	Reference	1.10	(0.98- 1.23)	0.09	0.08	Reference	1.14	(1.02- 1.27)	0.02	0.31
	yes	Reference	1.54	(1.10- 2.14)	0.01		Reference	0.98	(0.73- 1.32)	0.90	
Drinking status	no drinker	Reference	1.09	(0.95- 1.24)	0.22		Reference	1.19	(1.05- 1.36)	0.01	
	< 44g/day	Reference	1.22	(1.02- 1.46)	0.03	0.36	Reference	1.04	(0.87- 1.25)	0.65	0.33
	≥44g/day	Reference	1.46	(0.84- 2.54)	0.18	0.40	Reference	0.98	(0.59- 1.62)	0.93	0.54
Meals before going to bed	< 3times/week	Reference	1.16	(0.90- 1.47)	0.25	0.94	Reference	1.19	(0.94- 1.51)	0.15	0.79
	≥ 3times/week	Reference	1.14	(1.02- 1.28)	0.03		Reference	1.11	(0.99- 1.25)	0.07	
Digestive surgery	no	Reference	1.12	(1.00- 1.25)	0.05	0.19	Reference	1.12	(1.01- 1.25)	0.04	0.92
	yes	Reference	1.53	(1.02- 2.27)	0.04		Reference	1.14	(0.78- 1.67)	0.49	
Lifestyle-related diseases	no	Reference	1.07	(0.92- 1.23)	0.02	0.20	Reference	1.06	(0.92- 1.22)	0.39	0.31
	yes	Reference	1.24	(1.06- 1.45)	0.01		Reference	1.20	(1.03- 1.40)	0.02	
Subjective symptoms	nothing	Reference	1.14	(1.02- 1.29)	0.03		Reference	1.16	(1.03- 1.30)	0.01	
	1 symptom	Reference	1.04	(0.78- 1.37)	0.81	0.46	Reference	0.94	(0.72- 1.20)	0.66	0.16
	2 or more	Reference	1.37	(0.87- 2.16)	0.17	0.45	Reference	1.12	(0.73- 1.71)	0.61	0.94

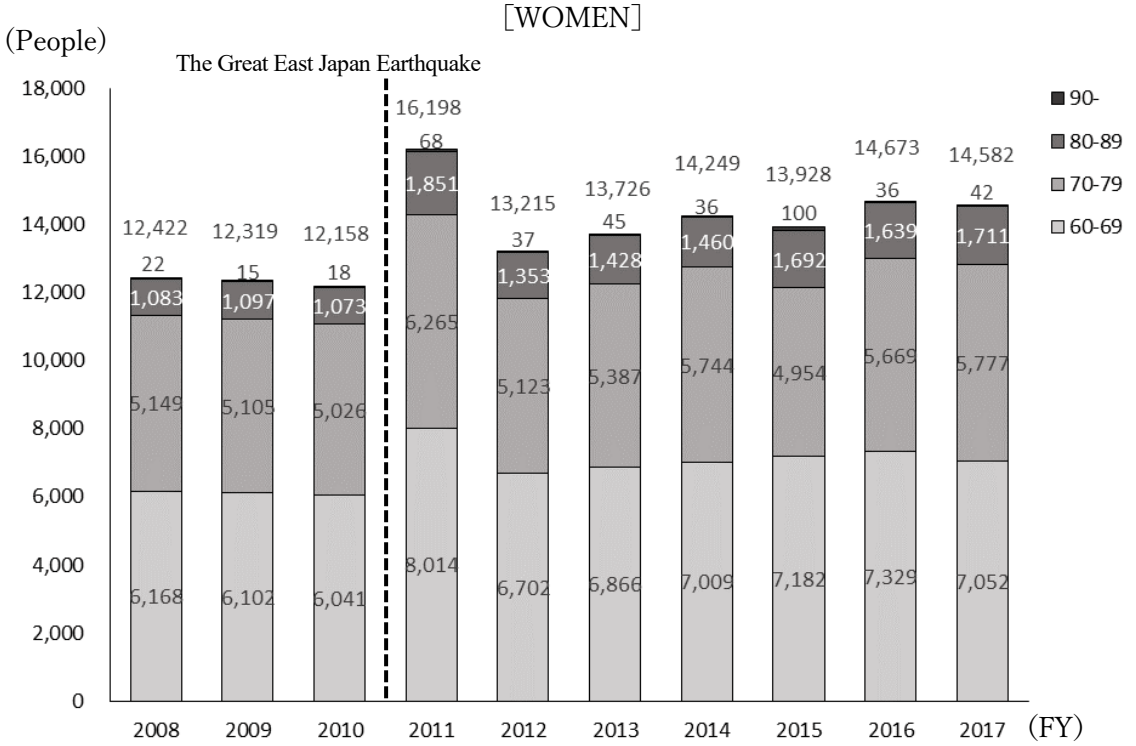
HR; Hazard ratio. CI; confidence interval.

*1 Adjustment variables included in the model: Age, Sex, Evacuation, Exercise habits, Smoking status, Drinking status, Meals before going to bed, Digestive surgery, Lifestyle-related diseases, and Subjective symptoms.

*2 Adjustment variables included in the model: Age, Sex, Evacuation, Physical activity, Smoking status, Drinking status, Meals before going to bed, Digestive surgery, Lifestyle-related diseases, and Subjective symptoms.



Examination years (FY: fiscal year)



Examination years (FY: fiscal year)

Figure1. Changes in the number of participants and age composition in each fiscal year age of over 60 years by sex

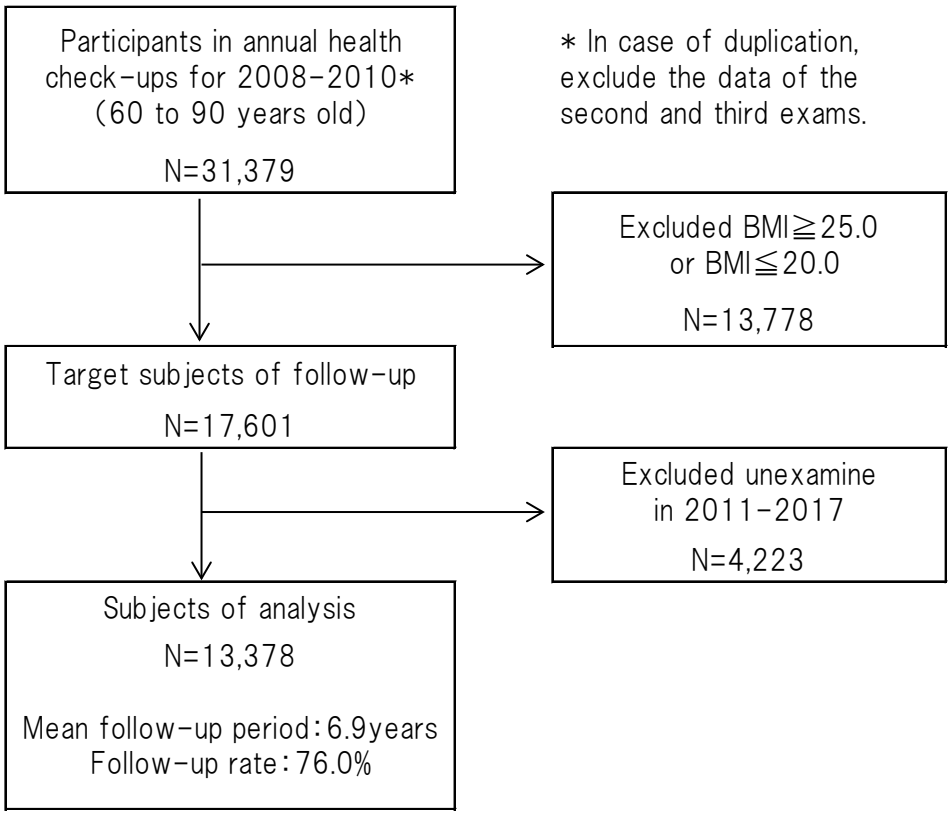


Figure 2. Extraction process of the analysis targets

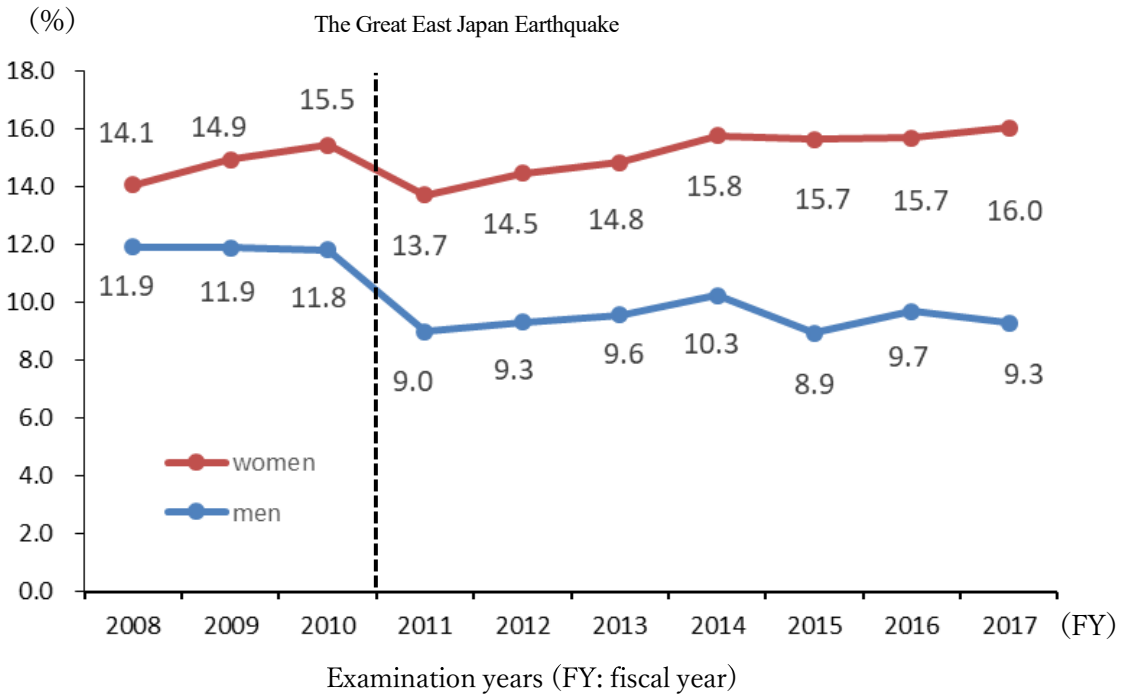
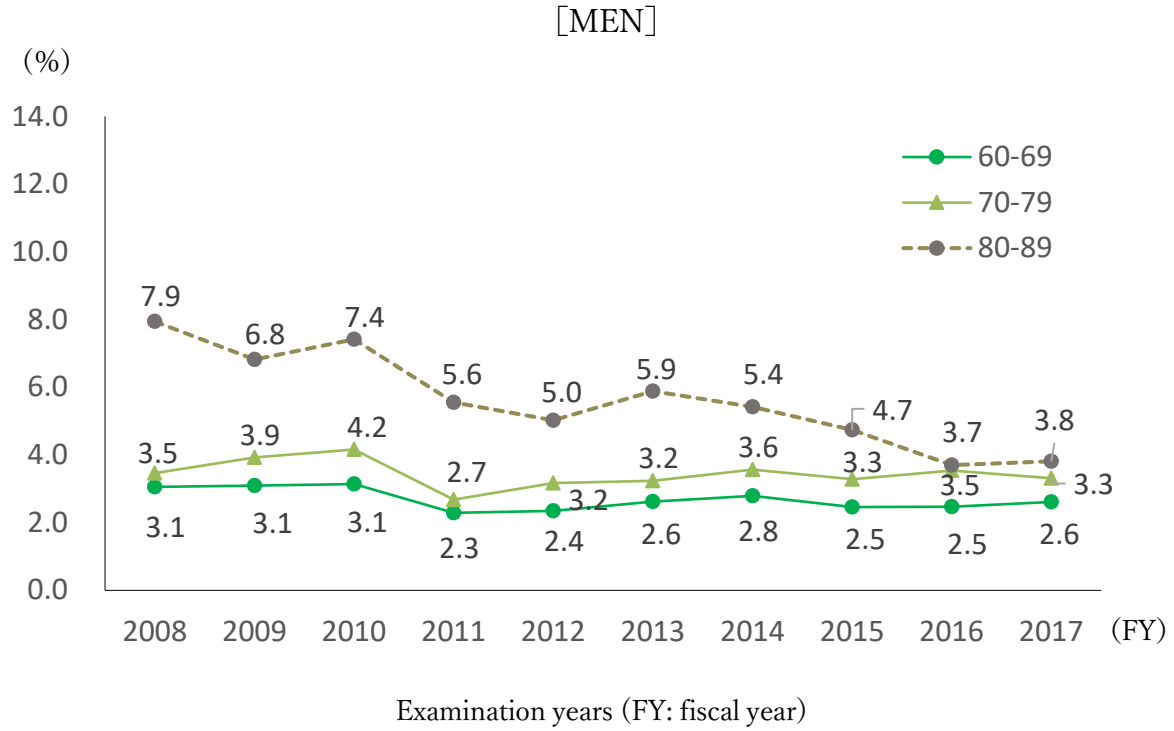


Figure 3. Trends in the prevalence of undernutrition before and after the disaster age of over 60 years by sex



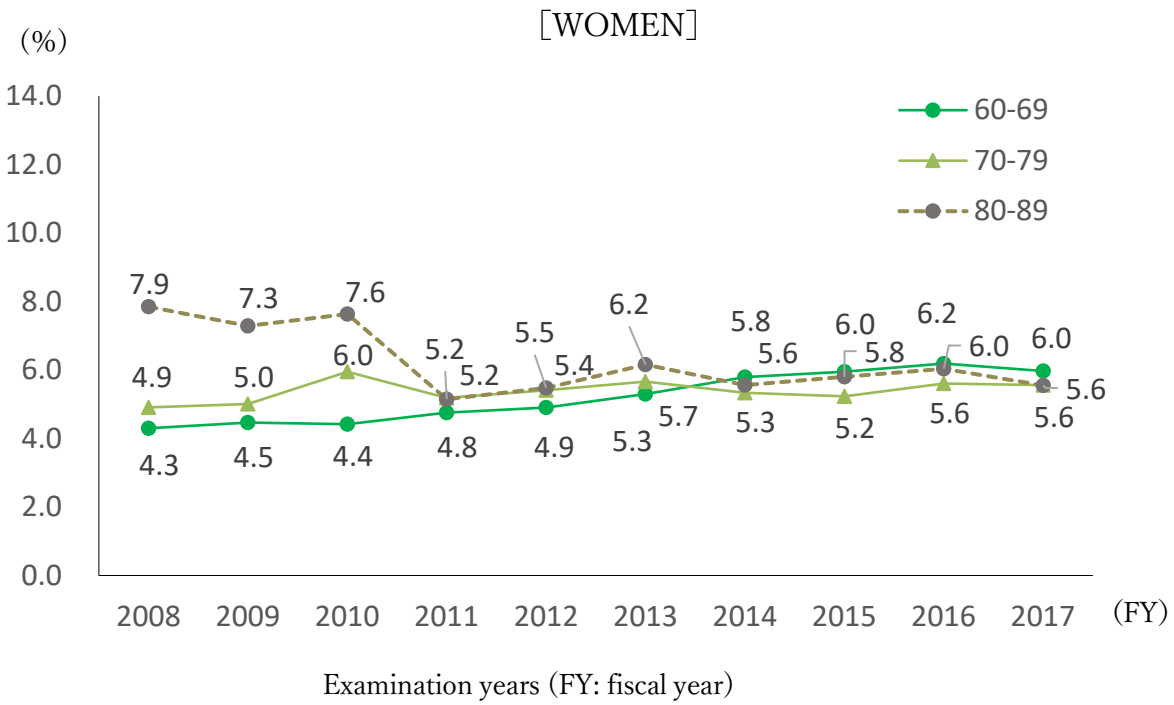
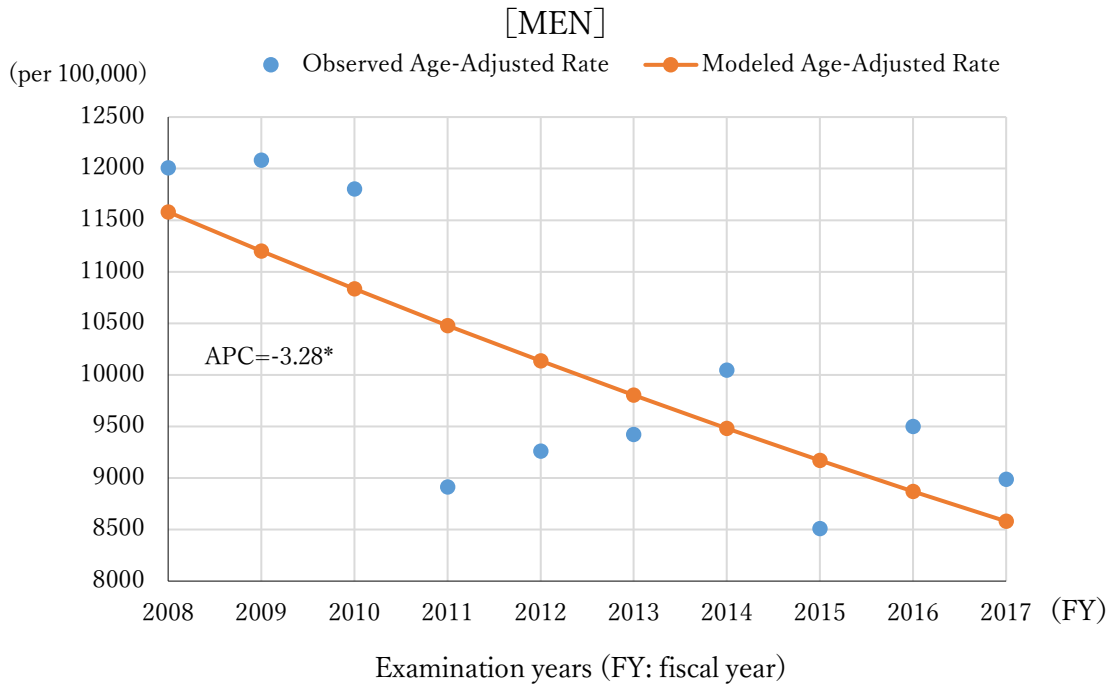


Figure 4. Trends in the prevalence of undernutrition before and after disaster age of over 60 years stratified by gender and age composition



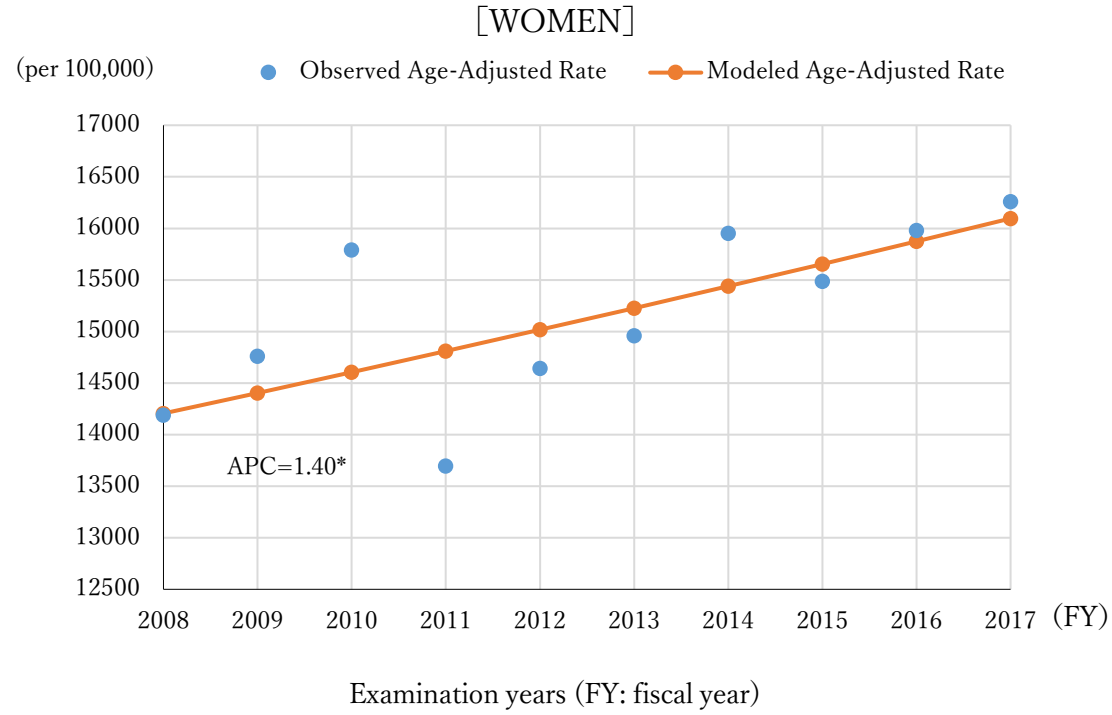


Figure 5. Trends in age-adjusted prevalence of undernutrition by sex, by Joinpoint regression (2008–2017)

*indicates that the Annual percent Change (APC) is significantly different from zero at the alpha=0.05 revel

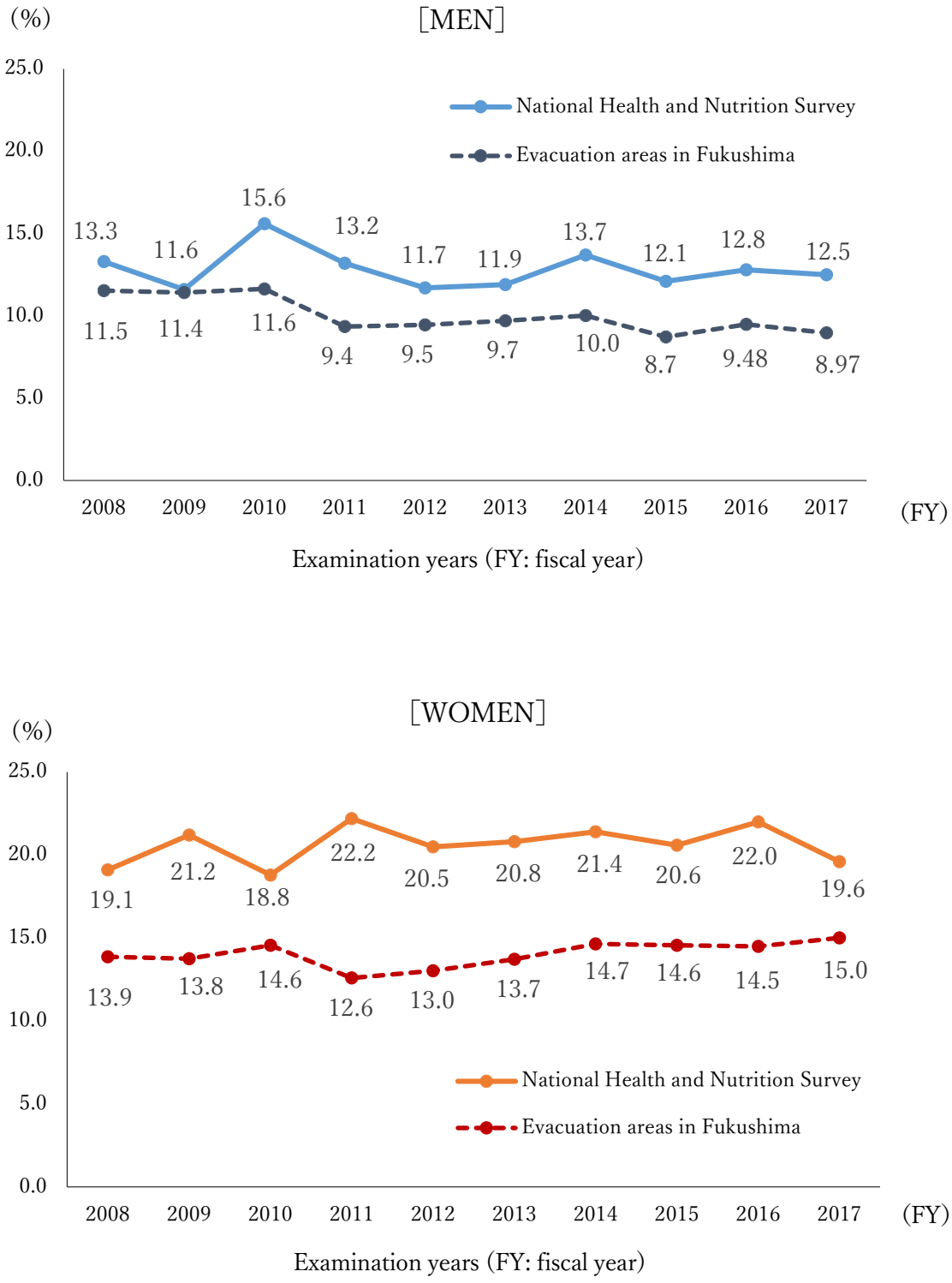


Figure 6. Comparison with national data for trends in the prevalence of undernutrition before and after the disaster age of over 65 years stratified by sex