



## Association of disaster-related damage with inflammatory diet among older survivors of the Great East Japan Earthquake and Tsunami

Aki Yazawa<sup>1,2\*</sup>, Hiroyuki Hikichi<sup>3</sup>, Koichiro Shiba<sup>4</sup>, Sakurako Shiba Okuzono<sup>1</sup>, Katsunori Kondo<sup>5,6</sup>, Satoshi Sasaki<sup>7</sup> and Ichiro Kawachi<sup>1</sup>

<sup>1</sup>Department of Social and Behavioral Sciences, Harvard T.H. Chan School of Public Health, Boston, MA, USA

<sup>2</sup>Department of Epidemiology and Prevention, Center for Clinical Sciences, National Center for Global Health and Medicine, Tokyo, Japan

<sup>3</sup>Division of Public Health, Kitasato University School of Medicine, Kanagawa, Japan

<sup>4</sup>Department of Epidemiology, Boston University School of Public Health, Boston, MA, USA

<sup>5</sup>Department of Social Preventive Medical Sciences, Center for Preventive Medical Sciences, Chiba University, Chiba, Japan

<sup>6</sup>Department of Gerontological Evaluation, Center for Gerontology and Social Science, Research Institute, National Center for Geriatrics and Gerontology, Obu, Aichi, Japan

<sup>7</sup>Department of Social and Preventive Epidemiology, School of Public Health, The University of Tokyo, Tokyo, Japan

(Submitted 12 October 2023 – Final revision received 5 January 2024 – Accepted 11 January 2024)

### Abstract

Traumatic experiences from disasters have enduring effects on health, both directly and indirectly by influencing health behaviours. Among potential pathways, the impact of disaster-related trauma on dietary patterns has been understudied. This study investigated the relationship between disaster-related trauma and dietary inflammatory index (DII<sup>®</sup>), and how these relationships differed by gender and whether they prepare meal by themselves or not among older survivors of the 2011 Great East Japan Earthquake and Tsunami (*n* 1375). Dietary data were collected in 2020 using a brief-type self-administered diet history questionnaire, from which we derived a dietary inflammatory index (DII<sup>®</sup>) based on twenty-six food/nutrient items, where higher scores indicate pro-inflammatory (i.e. unhealthy) diet. We found that the experience of housing damage due to the earthquake and tsunami was associated with slightly higher DII scores (coef. = 0.38, 95 % CI –0.05, 0.81). Specifically, women who cooked by themselves tended to have higher DII when they experienced housing damage (coef. = 1.33, 95 % CI –0.63, 3.28). On the other hand, loss of friends was associated with a lower DII score (coef. = –0.28, 95 % CI –0.54, –0.01). These findings highlight the importance of providing support to groups who are at increased risk of deterioration in dietary quality in the aftermath of disasters.

**Keywords:** Disaster: BDHQ: Japan: Gerontology: Inflammation

Experiencing a major disaster such as earthquake can exert lingering impacts on health, directly and indirectly through alteration of health behaviours, including dietary behaviours<sup>(1,2)</sup>. Despite its fundamental role in determining health outcomes, long-term impact of disaster experience on diet<sup>(3)</sup> has been less studied among older people who are prone to disease and are vulnerable to disaster damages<sup>(4)</sup>.

Disasters can potentially lead to changes in dietary behaviours through several hypothetical pathways. First, disaster-related trauma can affect mental health, which in turn affects people's appetite and dietary habits, e.g. choice of food items<sup>(5)</sup>. It has been shown that those with depression are more likely to consume high fat and sugar foods while fewer fruits and

vegetables<sup>(6)</sup>, and these associations can be different between men and women<sup>(7,8)</sup>. A previous study showed that older people suffering from post-traumatic stress symptoms (PTSS) and/or depression a decade after the Great East Japan Earthquake and Tsunami reported less consumption of Japanese traditional diet high in vegetables, soya products and fruits<sup>(9)</sup>. Notably, men showed unhealthy dietary pattern when they lived alone or were unmarried and suffered from mental problems, while women did not show such difference according to their marital status. Second, disaster-related loss of a spouse can also affect survivors' eating habits: older adults who experience widowhood are known to face challenges in maintaining the quality of their diet<sup>(10,11)</sup>. This may be due to various factors, including a lack of

**Abbreviations:** DII, dietary inflammatory index; BDHQ, brief-type self-administered diet history questionnaire; PTSS, post-traumatic stress symptoms; GDS, Geriatric Depression Scale.

\* **Corresponding author:** Aki Yazawa, email [aki.yazawa@gmail.com](mailto:aki.yazawa@gmail.com)



motivation to cook for eating alone, as well as changes in daily routines. In addition, increased loneliness due to death of spouse, family or friends can diminish the social reasons for and pleasures associated with, eating<sup>(12,13)</sup>. Third, other disaster-related experiences, such as residential displacement, can produce changes in the diet due to alterations in the home environment (e.g. the inconvenience of cooking meals in temporary housing with cramped kitchen space) or changes in the local food environment<sup>(14,15)</sup>.

Disaster-related traumas may increase a specific dietary pattern: pro-inflammatory diet, which is characterised by a high intake of refined grains, sugars, red and processed meat, eggs, high-fat dairy products, artificially sweetened drinks and salt<sup>(16)</sup>. Pro-inflammatory diet may increase after disasters because emotional distress may make people turn to comfort foods that are typically high in sugars and unhealthy fats, as well as limited access to fresh food and cooking facilities in the aftermath of the disaster can alter their cooking behaviour and lead to an increased reliance on processed and packaged foods. There has been exponential growth in the literature linking dietary inflammation to health. A systematic review of sixteen studies by Chen *et al.*<sup>(17)</sup> concluded that adults in the highest dietary inflammatory index (DII<sup>®</sup>) category showed significantly higher odds for depressive symptoms compared with the lowest DII category (OR = 1.28, 95% CI 1.17, 1.39). There also are longitudinal studies showing that the inflammatory dietary pattern is associated with a higher depression risk<sup>(18,19)</sup>. Pro-inflammatory diet has been linked to other health outcomes including functional disability<sup>(20)</sup>, frailty<sup>(20,21)</sup>, CVD<sup>(22–24)</sup>, dementia<sup>(25)</sup> and mortality<sup>(22,26)</sup>. Despite its importance, there have been limited studies investigating the link between disaster experiences and eating behaviours. Specifically, research considering pre-disaster depression is notably scarce, and the issue of reverse causality remains unresolved.

In this study, we sought to investigate the impact of disaster damages on the dietary inflammatory score conditional on pre-disaster characteristics including depressive symptoms among older survivors 9 years after the Great East Japan Earthquake and Tsunami (GLIDE number: #EQ-2011-000028-JPN). In Japan, women are overwhelming more likely to be involved in household chores including preparing meals compared with men<sup>(27)</sup>. In addition, as individuals advance in age, people tend to rely on other family members to undertake cooking responsibilities on their behalf, particularly as they become more frail. In this study, we investigated the impact of disaster damages on the DII, where higher scores indicate pro-inflammatory (i.e. unhealthy) diet, and how these relationships differed between genders or meal preparation habit. We hypothesised that those who experienced disaster damages would have higher DII.

## Methods

### Data

The data used in this study were obtained from the Iwanuma Study, which is a part of a larger national cohort study of Japanese older adults called the Japan Gerontological Evaluation Study<sup>(28)</sup>. The study was conducted in Iwanuma city, which was

one of the field sites of the Japan Gerontological Evaluation Study located in Miyagi Prefecture with a population of 44 187 in 2010. The baseline survey was conducted in August 2010, seven months prior to the Great East Japan Earthquake and Tsunami of March 11, 2011 (the Richter scale: 9.0). The the Japan Gerontological Evaluation Study conducted a census of all residents over the age of 65 in Iwanuma city (*n* 8576) and received valid responses from 4957 residents (response rate = 57.8%). The study participants were representative of the population of Iwanuma city as a whole<sup>(29)</sup>.

The earthquake and tsunami resulted in the loss of 180 lives, damage to 5542 homes and the flooding of 48% of the land area of Iwanuma city. Many survivors were forced to relocate to temporary housing or subsidised apartments on the rental market. The first follow-up survey was conducted in 2013, 2.5 years after the disaster, for all baseline cohort survivors. Of the 4380 eligible survivors who lived in Iwanuma city, 3567 people responded to the mailed survey (follow-up rate: 81.4%). In January 2020, approximately 9 years after the disaster, dietary data were obtained from a follow-up survey (*n* 2573, follow-up rate 79.6%) using the brief-type self-administered diet history questionnaire (BDHQ), which is a validated self-administered food frequency questionnaire based on the consumption frequency of fifty-eight food and beverage items during the preceding month<sup>(30–32)</sup>. BDHQ is a short version of a comprehensive self-administered diet history questionnaire (DHQ: 150-item semi-quantitative questionnaire) that includes food and beverage items commonly consumed in Japan. The validity of BDHQ was confirmed by comparing nutrient intake against DHQ using semi-weighed 16-day dietary records as reference, and its short-term test-retest reliability of eating habits has also been established<sup>(33)</sup>. A total of 1531 individuals participated in both the 2010 and 2013 surveys and completed the dietary survey in 2020. After excluding individuals who did not provide information on weight and height (*n* 4), or reported an energy intake less than half of the energy requirement for the lowest physical activity category (< 725 kcal/d; *n* 7) or more than 1.5 times of the energy requirement for the highest physical activity category (> 3300 kcal/d; *n* 118) of the recommended amount by the Dietary Reference Intakes for Japanese<sup>(34)</sup>, the analytical sample was reduced to 1375. The sample selection strategy is illustrated in Fig. 1.

### Measurements

**Pre-disaster variables.** The source of our pre-disaster variables is the baseline survey data collected in 2010, which included age (in years), gender (men; women), marital status (married; not married), educational attainment (less than 10 years; 10–12 years; 13 years or more), equivalent household income (less than 200; 200–399; more than 400 million yen), depressive symptoms (no; mild; severe), employment status (currently working; retired; never), BMI, self-rated health (poor; fair; good and excellent), protein consumption (less than once a week; two to three times a week; four to six times a week; once a day and twice or more a day), fruit and vegetable consumption (two to three times a week or less; four to six times a week; once a day and twice or more a day), smoking (never; has stopped > 5 years



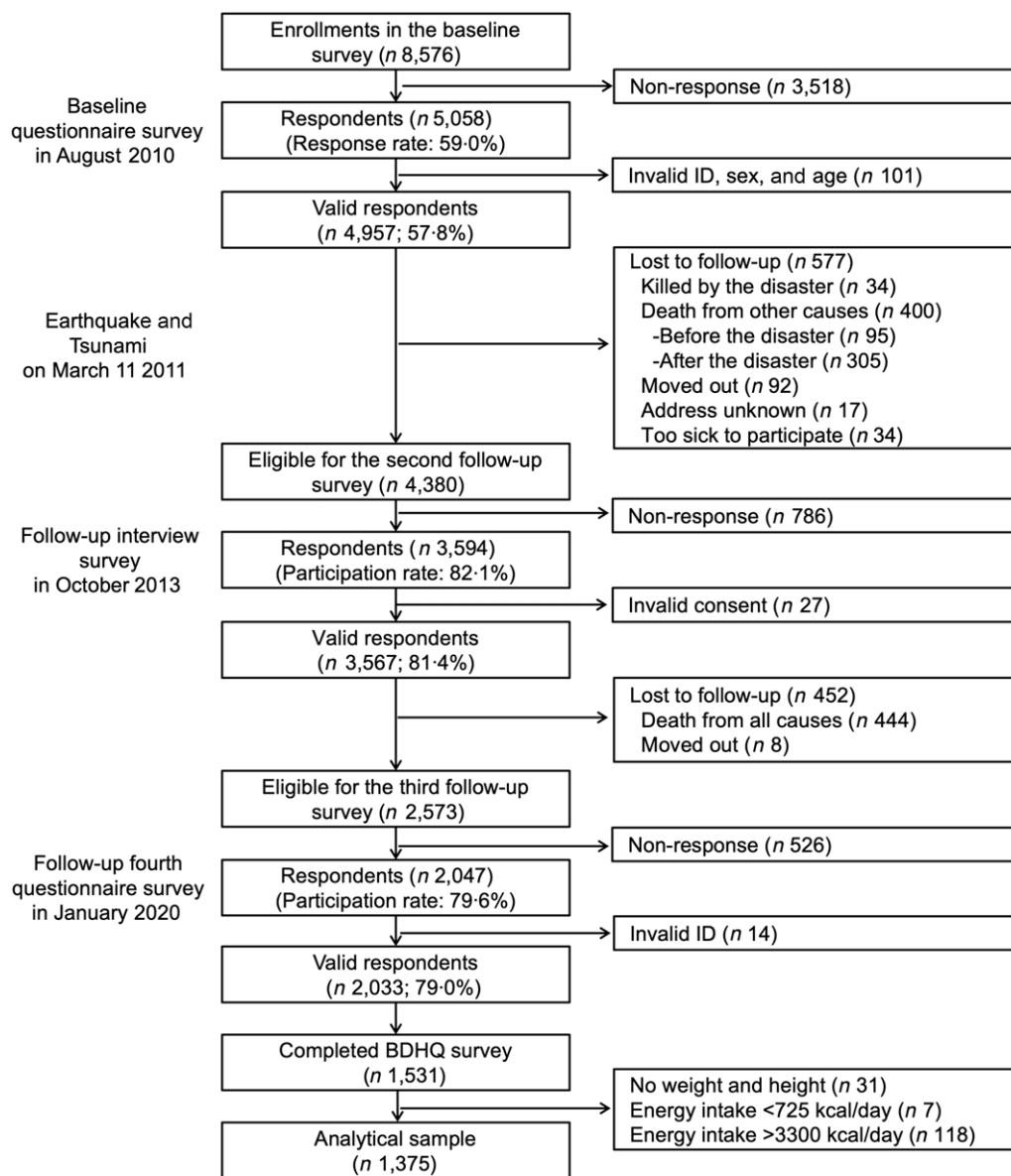


Fig. 1. Flow of the sampling strategy.

ago; has stopped within 4 years and current smoker) and alcohol drinking (never; stopped and current drinker). Depressive symptoms were evaluated using the Japanese version of the Geriatric Depression Scale<sup>(35–37)</sup>. The answers to each of the fifteen binary (yes/no) questions were added together to yield a total score ranging from 0 to 15. A score between 5 and 9 was indicative of mild depressive symptoms, whereas a score of 10 or higher was indicative of severe depressive symptoms. For a *post hoc* analysis, data on frequency of meeting friends were obtained (almost everyday; two or three times a week; once a week; once or twice a month and a few times a year and never).

**Disaster damages and post-disaster stress symptoms.**

Participants' experience of five types of disaster damages was retrieved from the follow-up survey in 2013, which includes housing damage (major damage/complete destruction *v.* less

extensive damage), job loss (yes; no), economic loss (yes; no), loss of relatives (yes; no) and loss of friends (yes; no). In addition, whether they relocated after the disaster was obtained (yes; no). PTSS were also assessed in 2013 using the Screening Questionnaire for Disaster Mental Health<sup>(29,38)</sup>. The questionnaire was originally developed to evaluate the PTSS among Japanese older survivors of the Hanshin-Awaji Earthquake in 1995 (Richter scale: 7.3, GLIDE number: #EQ-1995-000003-JPN), which has been validated against the Clinician Administered PTSD Scale and the Impact of Event Scale-Revised<sup>(38)</sup>. Participants answered nine questions with binary (yes/no) responses, and the total score was calculated (0–9) and categorized into three: no PTSS (0–3), mild (4–5) and severe (6–9) symptoms<sup>(38)</sup>.

**Meal preparation status.** In the 2020 survey, we asked a question to determine if participants prepare their own meals.

The question asked was 'Can you cook for yourself?' and respondents had three answer options: 'Yes, I can and do,' 'Yes, I can but usually don't' and 'No, I can't.' We created a binary variable to indicate whether participants prepared their own meals by combining the last two answer options into a single category.

**Dietary inflammatory index.** The DII is a tool used to assess the inflammatory potential of an individual's diet quantitatively. The DII is calculated based on the intake of several nutrients and foods that have been shown to have either anti-inflammatory or pro-inflammatory effects. In this study, DII was calculated by the twenty-six food parameters obtained in the BDHQ following the methods described previously<sup>(39,40)</sup>, which includes alcohol, vitamin B<sub>12</sub>, vitamin B<sub>6</sub>,  $\beta$ -carotene, carbohydrate, cholesterol, energy, total fat, fibre, folic acid, Fe, Mg, MUFA, niacin, *n*-3 fatty acids, *n*-6 fatty acids, protein, PUFA, riboflavin, saturated fat, thiamine, vitamin A, vitamin C, vitamin E, Zn and tea.

First, we determined the relative exposure to each food/nutrient by subtracting the amount of each food/nutrient with the global daily mean intake and dividing it by the standard deviation derived from the world composite database. Second, to minimise the impact of right skewing, we converted the relative exposure values to a centered percentile score. This involved doubling each percentile score and then subtracting by one to create a symmetrical distribution with a range from -1 (maximally anti-inflammatory) to 1 (maximally pro-inflammatory). Third, the value for each parameter was multiplied by the food and nutrient-specific inflammatory effect scores provided by Shivappa *et al.*<sup>(40)</sup> to calculate the DII score for each food and nutrient. These scores are based on an extensive review of the previous scientific literature. Finally, these scores were summed to create the overall DII score (ranged -5.3 to 4.5 in the study participants, where higher scores indicate more pro-inflammatory diet).

### Statistical analysis

Least-squares linear regression was conducted to investigate the association between disaster-related trauma and dietary inflammatory index and how these relationships differed by gender and meal preparation status. Model 1 included disaster damages and PTSS, gender and whether the respondent prepared their meals, while Model 2 included the interaction term between disaster damage and gender to investigate potential gender differences in the impact of disaster experiences on diet. Model 3 further incorporated a three-way interaction between gender \* disaster damage \* whether the respondent prepared their own meals. Covariates included age, marital status, educational attainment, household equivalent income, employment status, BMI, self-rated health, frequency of protein/vegetable intake, smoking, alcohol consumption and depressive symptoms in 2010.

Missing values were imputed by the Markov chain Monte Carlo methods to generate twenty datasets<sup>(41)</sup> for those who provided dietary data. The level of statistical significance was set at  $P < 0.05$  (two-tailed). All statistical analyses were conducted using Stata 16.1 or 17.1 (StataCorp).

## Results

**Table 1** presents the characteristics of study participants. The mean age was 70.9 years (standard deviation of 4.5) in 2010 and 44.6% were men. In terms of disaster damages, 6.8% experienced major housing damage, 6.4% experienced job loss, 22.1% experienced economic loss, 28.1% lost their relatives, 17.5% lost friends in the earthquake and tsunami, and 27% experienced mild to severe PTSS. In 2020, 68.5% reported that they prepared their own meals.

**Table 2** shows the results regressing DII scores on types of disaster damage. Model 1 revealed that major housing damage was associated with a slightly higher DII score (coef. = 0.38, 95% CI -0.05, 0.81), which was not statistically significant, while loss of friends was associated with a lower DII score (coef. = -0.28, 95% CI -0.54, -0.01). Participants who prepared their own meals showed higher DII scores (coef. = 0.31, 95% CI 0.05, 0.57). Subsequent analyses with interaction terms were conducted only for major housing damage. Model 2 found an interaction between gender and housing damage ( $P = 0.056$ ); women who experienced housing damage were more likely to show a higher DII score. Three-way interaction (Model 3) indicated that women who prepared their own meals tended to show higher DII scores when they experienced housing damage, although the interaction was not statistically significant (**Fig. 2**). Online Supplementary Table 1 displays the results of Model 1, encompassing all the estimates including those for covariates for additional information.

## Discussion

### Summary of the findings

This study used a long-term follow-up data of the Great East Japan Earthquake and Tsunami to evaluate the impact of the disaster on the inflammatory profile of the diet conditional on pre-disaster characteristics among older disaster survivors. Among the types of disaster damages, housing damage was associated with slightly higher pro-inflammatory dietary scores 9 years after the disaster. Specifically, women had higher DII if they experienced housing damage. On the other hand, loss of friends was associated with a lower DII score.

### Housing damage and pro-inflammatory diet

As hypothesised, we found that the experience of housing damage was marginally associated with higher inflammatory diet scores. Shiba *et al.*<sup>(42)</sup> reported that survivors who experienced home loss exhibited increased BMI and waist circumference, as well as decreased high-density lipoprotein cholesterol than those with less housing damage 2.5 years after the Great East Japan Earthquake and Tsunami. A long-term follow-up study of the survivors of the 1988 Spitak earthquake in Armenia similarly found that total home destruction was linked to the increased risk of diabetes after 23 years<sup>(43)</sup>. The present study suggests that post-disaster diet may be one of the pathways linking housing damage and worsened cardiometabolic profiles.

In this study, the positive association between housing damage and DII was more pronounced among women,



**Table 1.** Characteristics of the study participants (n 1375)

	Men (n 613)		Women (n 762)		Total	
	n	%	n	%	n	%
Pre-disaster characteristics						
Age						
Mean	71.1		70.8		70.9	
SD	4.6		4.4		4.5	
Marital status (Married) (n 1355)	559	92.4	511	68.1	1070	79.0
Education						
Less than 10 years	153	25.0	210	27.6	363	26.4
10–12 years	277	45.2	401	52.6	678	49.3
13 years or more	183	29.9	151	19.8	334	24.3
Equivalent income						
Less than 200 million yen	252	41.1	295	38.7	547	39.8
200–399 million yen	267	43.6	286	37.5	553	40.2
More than 400 million yen	94	15.3	181	23.8	275	20.0
Employment (n 1274)						
Yes	177	29.7	117	17.3	294	23.1
Retired	400	67.0	403	59.5	803	63.0
Never	20	3.4	157	23.2	177	13.9
BMI (n 1344)						
Mean	23.6		23.4		23.5	
SD	2.6		3.3		3.0	
Self-rated health						
Poor	6	1.0	7	0.9	13	1.0
Fair	59	9.6	70	9.2	129	9.4
Good	452	73.7	572	75.1	1024	74.5
Excellent	96	15.7	113	14.8	209	15.2
Protein consumption						
Less than once a week	34	5.6	31	4.1	65	4.7
Two to three times a week	164	26.8	168	22.1	332	24.2
Four to six times a week	143	23.3	143	18.8	286	20.8
Once a day	216	35.2	312	40.9	528	38.4
Twice or more a day	56	9.1	108	14.2	164	11.9
Fruit and vegetable consumption						
Two to three times a week or less	35	5.7	32	4.2	67	4.9
Four to six times a week	72	11.8	55	7.2	127	9.2
Once a day	210	34.3	190	24.9	400	29.1
Twice or more a day	296	48.3	485	63.7	781	56.8
Smoking (n 1306)						
Never	161	26.6	648	92.6	809	61.9
Has stopped ≥ 5 years ago	273	45.1	21	3.0	294	22.5
Has stopped within 4 years	54	8.9	7	1.0	61	4.7
Current smoker	118	19.5	24	3.4	142	10.9
Alcohol drinking (n 1361)						
Never	143	23.4	608	81.1	751	55.2
Stopped	27	4.4	5	0.7	32	2.4
Current drinker	441	72.2	137	18.3	578	42.5
Depression						
No	424	69.2	503	66.0	927	67.4
Mild	112	18.3	128	16.8	240	17.5
Severe	77	12.6	131	17.2	208	15.1
Disaster damages						
Major housing damage (n 1354)	36	5.9	56	7.5	92	6.8
Job loss (n 1224)	44	7.8	34	5.2	78	6.4
Economic loss (n 1360)	132	21.8	168	22.3	300	22.1
Loss of relatives	151	24.6	235	30.8	386	28.1
Loss of friends	116	18.9	124	16.3	240	17.5
Post-traumatic stress symptoms						
No	493	80.4	513	67.3	1006	73.2
Mild	60	9.8	125	16.4	185	13.5
Severe	60	9.8	124	16.3	184	13.4
Current meal preparation (Yes) (n 1363)	244	40.1	689	91.4	933	68.5

Mean (standard deviation)/n (%) are shown.

especially for those who cooked by themselves. It has been shown that women are more susceptible to changes in the neighbourhood environment compared with men<sup>(44,45)</sup>. Shiba *et al.*<sup>(15)</sup> examined changes in neighbourhood environment after

the Great East Japan Earthquake and Tsunami in relation to changes in cardiometabolic markers. In stratified analysis, women who moved to more dense areas (e.g. more food facilities, convenience stores) showed an increase in BMI,



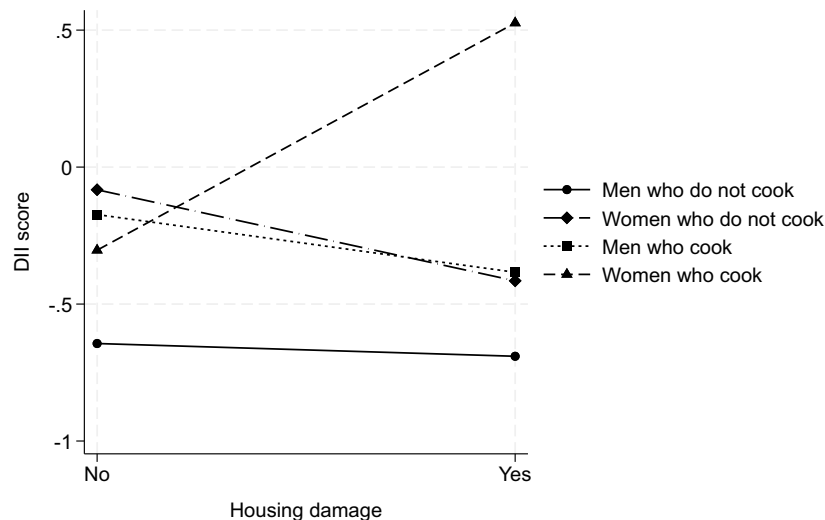
**Table 2.** Disaster damages and post-traumatic-stress symptoms after the disaster and dietary inflammatory index among older survivors of 2011 great east Japan earthquake and Tsunami in 2020 (*n* 1375)

	Model 1		Model 2		Model 3	
	Coefficients	95 % CI	Coefficients	95 % CI	Coefficients	95 % CI
Disaster damages						
Major housing damage	0.38†	-0.05, 0.81	-0.11	-0.77, 0.55	-0.06	-0.86, 0.74
Job loss	-0.16	-0.63, 0.31	-0.15	-0.62, 0.32	-0.17	-0.64, 0.29
Economic loss	0.02	-0.25, 0.30	0.03	-0.24, 0.30	0.01	-0.26, 0.27
Loss of relatives	-0.08	-0.31, 0.15	-0.08	-0.31, 0.15	-0.09	-0.32, 0.14
Loss of friends	-0.28*	-0.54, -0.01	-0.27	-0.53, -0.00	-0.24	-0.50, 0.02
PTSS (ref. no)						
Mild PTSS	-0.07	-0.38, 0.23	-0.07	-0.38, 0.23	-0.07	-0.37, 0.24
Severe PTSS	0.04	-0.34, 0.42	0.02	-0.36, 0.40	0.02	-0.35, 0.40
Gender (women)	0.05	-0.31, 0.40	-0.00	-0.36, 0.35	0.56	-0.04, 1.17
Prepare own meals (yes)	0.31*	0.05, 0.57	0.31	0.05, 0.57	0.47	0.16, 0.78
Interaction terms						
Housing damage × Women			0.79†	-0.02, 1.60	-0.29	-1.82, 1.25
Housing damage × Meal preparation					-0.16	-1.52, 1.20
Women × Meal preparation					-0.69	-1.30, -0.08
Housing damage × Women × Meal preparation					1.33	-0.63, 3.28

\*  $P < 0.05$ .

†  $P < 0.1$ . PTSS, post-traumatic stress symptoms.

Least-squares linear regression analyses were conducted separately for three models. Coefficients (95 % CI) are shown. Covariates included age, marital status, educational attainment, household equivalent income, employment status, BMI, self-rated health, frequency of protein/vegetable intake, smoking, alcohol consumption and depression in 2010. Sample sizes for interaction terms: housing damage (yes) × women (*n* 56), housing damage (no) × women (*n* 691), housing damage (yes) × men (*n* 36), housing damage (no) × men (*n* 571); housing damage (yes) × women × meal preparation (yes) (*n* 46), housing damage (no) × women × meal preparation (yes) (*n* 630), housing damage (yes) × women × meal preparation (no) (*n* 9), housing damage (no) × women × meal preparation (no) (*n* 54), housing damage (yes) × men × meal preparation (yes) (*n* 12), housing damage (no) × men × meal preparation (yes) (*n* 229), housing damage (yes) × men × meal preparation (no) (*n* 23), housing damage (no) × men × meal preparation (no) (*n* 339).



**Fig. 2.** Interaction between gender, housing damage and meal preparation on the Dietary Inflammatory Index score.

but the association was less pronounced among men. Changes in neighbourhood environments in the aftermath of the earthquake may have caused the dietary change especially among women.

Women are also psychologically more vulnerable in the aftermath of disasters<sup>(46)</sup>. After the Great East Japan Earthquake and Tsunami, women were 1.6 times more likely to experience PTSS<sup>(47)</sup>. According to the current study's data, women were also 1.1 times more likely to experience the new onset of depressive symptoms compared with male survivors (seventy out of 424 men (16.5 %) *v.* 93 out of 503 women (18.5 %)). Depression and PTSS are strong predictors of emotional eating, and studies have shown that emotional eating is more frequently observed among

women than men and contribute to weight gain<sup>(48,49)</sup>. Emotional eating is usually characterised by a decrease in the consumption of fruits and vegetables<sup>(50)</sup>, which are generally known for their anti-inflammatory properties, and an increase in the intake of energy-dense fast foods, sweets and confectionery<sup>(51,52)</sup>, which tend to be more pro-inflammatory<sup>(53)</sup>. Even in the absence of depression/PTSS, individuals who have experienced housing damages are likely to face persistent daily stressors, which are known to be associated with increased consumption of high fat/sugar snacks and with a reduction in main meals and vegetable consumption, indicating a pro-inflammatory diet, which is particularly prominent among women<sup>(54)</sup>. While we

have controlled for pre- and post-disaster mental status, psychological impact of disaster and behavioural changes due to it may be more pronounced among women, resulting in higher consumption of pro-inflammatory diet. Another important factor to consider is that, generally, women are significantly more prone to participating in meal preparation compared with men in Japan<sup>(27)</sup>. The fact that the association between housing damage and inflammatory diet was observed mainly among women who cooked by themselves may suggest that women who do not cook probably have their family members cook for them. This is a hypothetical scenario derived from the results, which should be validated in future studies.

It is also anticipated that the experience of living in a temporary housing may have had a greater impact on the cooking habits of women compared with men. Many people who suffered housing damage relocated to temporary housing called *kasetsu jutaku*, which have very small kitchens. Such condition may have shifted dietary behaviour towards consumption of more fast foods or simple meals<sup>(55)</sup>. While there was only twenty-one people who moved to *kasetsu jutaku* in this study sample, they showed the higher DII score (mean 0.13 SD 1.9, not shown in Tables) compared with those who did not move (mean -0.35 SD 2.0) or those who bought a new house (mean -0.66 SD 1.8). There is also ethnographic research indicating dietary behaviour change after 4 years after the disaster (e.g. the presentation of dishes has shifted from individual servings to large shared plates due to limited space and people stopped making preserved foods, such as miso and pickled vegetables)<sup>(56)</sup>. It is possible that one of the pathways linking housing damage and pro-inflammatory diet is the experience of *kasetsu jutaku*. This is a hypothesis that requires empirical testing. Future studies are warranted to assess the long-term impact of relocation to temporary housing on dietary habits.

#### Loss of friends and pro-inflammatory diet

Contrary to our hypothesis, other disaster damages were not linked to an increased DII. Instead, the loss of friends was associated with a lower DII. The loss of friends might be linked to a reduced frequency of enjoying meals high in sugar and fat (e.g. snacks), but it is improbable that the influence of such occasional meals has been substantial enough to persist for a decade. One potential explanation for this association is that individuals who lost their friends in the disaster were more likely to be socially active and had a better diet before the disaster, which in turn contributed to their maintenance of a healthier diet after the disaster. We conducted a *post hoc* analysis using data from 2010 regarding the frequency of consuming protein, fruits and vegetables, as well as social interactions with friends. As shown in the online Supplementary Table 2, individuals who lost their friends in the disaster tended to have a slightly higher frequency of consuming protein, fruits and vegetables, as well as meeting with friends more often before the disaster. Since we did not conduct a pre-disaster dietary survey, it was impossible to observe dietary changes before and after the disaster. A future study is warranted to assess the impact of different types of disaster damages on dietary habits.

#### Limitations

Several limitations should be acknowledged within this study. First, the absence of pre-disaster dietary data is a notable limitation, although we did account for protein and vegetable intakes as well as alcohol consumption assessed in 2010. Second, the DII score was derived from self-reported food intake, which introduces the potential for recall bias, particularly among individuals with cognitive decline. It is also impossible to distinguish how the meals were prepared (e.g. homemade meals, meals purchased at grocery stores or meals at restaurants). Moreover, the use of complex dietary questionnaire and/or non-participation in the follow-up survey may have resulted in selection bias<sup>(57)</sup>. Third, while we considered PTSS as an exposure, it is plausible that it functions as a mediator between disaster damages (e.g. housing damage) and dietary habits. Given the potential existence of both direct and indirect pathways, future research should focus on comprehending the intricate relationship among disasters, mental dysfunction and health behaviours. Lastly, the generalisability of the findings may be limited to other age groups. Older people generally face challenges such as loss of appetite, change or loss in taste, tooth loss and reduced mobility<sup>(58–60)</sup>, which can further exacerbate the impact of prolonged burden from disaster damages.

#### Conclusion

Our study shows that nearly a decade after the Great East Japan Earthquake and Tsunami, the experience of housing damage leaves a lingering impact on the quality of individuals' diets. This sustained impact on dietary habits may have contributed to the deterioration of overall health in various aspects. Notably, this effect was particularly evident among women, who often take on more household responsibilities and are known to be more vulnerable to the environmental and psychological repercussions of disasters compared with men. These findings highlight the importance of providing support to groups who are at increased risk of deterioration in dietary quality in the aftermath of disasters.

#### Acknowledgements

This study used data from the Japan Gerontological Evaluation Study (the Japan Gerontological Evaluation Study). This study was supported by a grant from the National Institutes of Health (R01 AG042463), Japan Society for the Promotion of Science (JSPS) (KAKENHI Grant Numbers JP22390400, JP22592327, JP24390469, JP15H04781, JP15H01972, JP16H05556, JP19H03860, JP21J01171), Health Labour Sciences Research Grant (H28-Choju-Ippan-002), Japan Agency for Medical Research and Development (AMED) (JP18dk0110027, JP18ls0110002, JP18le0110009, JP20dk0110034, JP21lk0310073, JP21dk0110037), Open Innovation Platform with Enterprises, Research Institute and Academia (OPERA, JPMJOP1831) from the Japan Science and Technology (JST), a grant from Innovative Research Program on Suicide Countermeasures (1–4), a grant from Sasakawa Sports Foundation, a grant from Japan Health Promotion & Fitness Foundation, a grant from Chiba Foundation for Health Promotion &



Disease Prevention, the 8020 Research Grant for fiscal 2019 from the 8020 Promotion Foundation (adopted number: 19-2-06), grants from Welfare and the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (29–42, 30–22, 20–19, 21–20), a grant from Meiji, Obirin University and Niimi University (1915010). A.Y. is financially supported by JSPS Research Fellowship for Young Scientists. The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the respective funding organisations.

A.Y. and I.K.: Conceptualisation; H.H. and K.K.: data curation; A.Y.: formal analysis; K.K., I.K. and A.Y.: funding acquisition; K.K. and I.K.: investigation; A.Y., I.K. and S.S.: methodology; K.K. and I.K.: project administration; K.K. and I.K.: resources; A.Y.: software; I.K.: supervision; H.H. and K.S.: validation; A.Y.: visualisation; A.Y. and I.K.: roles/writing – original draft; K.S., S.S.O., H.H., S.S. and K.K.: writing – review and editing.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and the study involving human subjects/patients were approved by the Human Subjects Committee of the Harvard T.H. Chan School of Public Health (CR-23143-09), the Institutional Review Boards of Chiba University (protocol #3442), and Tokyo Medical & Dental University (D2021-025). Written informed consent was obtained from all subjects.

### Supplementary material

For supplementary material/s referred to in this article, please visit <https://doi.org/10.1017/S0007114524000217>

### References

- Goldmann E & Galea S (2014) Mental health consequences of disasters. *Annu Rev Public Health* **35**, 169–183.
- Rubeis VD, Lee J, Anwer MS, *et al.* (2021) Impact of disasters, including pandemics, on cardiometabolic outcomes across the life-course: a systematic review. *BMJ Open* **11**, e047152.
- Whitaker RC, Phillips SM, Orzol SM, *et al.* (2007) The association between maltreatment and obesity among pre-school children. *Child Abuse Negl* **31**, 1187–1199.
- Jia Z, Tian W, Liu W, *et al.* (2010) Are the elderly more vulnerable to psychological impact of natural disaster? A population-based survey of adult survivors of the 2008 Sichuan earthquake. *BMC Public Health* **10**, 172.
- Abbasalizad Farhangi M, Dehghan P & Jahangiry L (2018) Mental health problems in relation to eating behavior patterns, nutrient intakes and health related quality of life among Iranian female adolescents. *PLoS One* **13**, e0195669.
- Payne ME, Steck SE, George RR, *et al.* (2012) Fruit, vegetable, and antioxidant intakes are lower in older adults with depression. *J Acad Nutr Diet* **112**, 2022–2027.
- Mohamad O, Sabbah HA, Smail L, *et al.* (2022) Food Consumption Frequency, Perceived Stress, and Depressive Symptoms Among Female University Students in Dubai, United Arab Emirates. *Frontiers in Sustainable Food Systems* **6**.
- Zellner DA, Loaiza S, Gonzalez Z, *et al.* (2006) Food selection changes under stress. *Physiol Behav* **87**, 789–793.
- Yazawa A, Shiba K, Hikichi H, *et al.* (2023) Post-disaster mental health and dietary patterns among older survivors of an earthquake and Tsunami. *J Nutr Health Aging* **27**, 124–133.
- Rosenbloom CA & Whittington FJ (1993) The effects of bereavement on eating behaviors and nutrient intakes in elderly widowed persons. *J Gerontol* **48**, S223–229.
- Shahar DR, Schultz R, Shahar A, *et al.* (2001) The effect of widowhood on weight change, dietary intake, and eating behavior in the elderly population. *J Aging Health* **13**, 189–199.
- Shifflett PA & McIntosh WA (1987) Food habits and future time: an exploratory study of age-appropriate food habits among the elderly. *Int J Aging Hum Dev* **24**, 1–17.
- Walker D & Beauchene RE (1991) The relationship of loneliness, social isolation, and physical health to dietary adequacy of independently living elderly. *J Am Diet Assoc* **91**, 300–304.
- Hikichi H, Aida J, Kondo K, *et al.* (2019) Residential relocation and obesity after a natural disaster: a natural experiment from the 2011 Japan Earthquake and Tsunami. *Sci Rep* **9**, 1–11.
- Shiba K, Hanazato M, Aida J, *et al.* (2020) Cardiometabolic profiles and change in neighborhood food and built environment among older adults: a natural experiment. *Epidemiol* **31**, 758–767.
- Stromsnes K, Correias AG, Lehmann J, *et al.* (2021) Anti-inflammatory properties of diet: role in healthy aging. *Biomedicine* **9**, 922.
- Chen G-Q, Peng C-L, Lian Y, *et al.* (2021) Association between dietary inflammatory index and mental health: a systematic review and dose–response meta-analysis. *Front Nutr* **8**, 662357.
- Lucas M, Chocano-Bedoya P, Shulze MB, *et al.* (2014) Inflammatory dietary pattern and risk of depression among women. *Brain, Behav, Immun* **36**, 46–53.
- Sánchez-Villegas A, Ruíz-Canela M, Fuente-Arrillaga C, *et al.* (2015) Dietary inflammatory index, cardiometabolic conditions and depression in the Seguimiento Universidad de Navarra cohort study. *Br J Nutr* **114**, 1471–1479.
- Tomata Y, Shivappa N, Zhang S, *et al.* (2018) Dietary inflammatory index and disability-free survival in community-dwelling older adults. *Nutrients* **10**, 1896.
- Kim D & Park Y (2018) Association between the dietary inflammatory index and risk of frailty in older individuals with poor nutritional status. *Nutrients* **10**, E1363.
- Ruiz-Canela M, Bes-Rastrollo M & Martínez-González MA (2016) The role of dietary inflammatory index in cardiovascular disease, metabolic syndrome and mortality. *Int J Mol Sci* **17**, E1265.
- Shivappa N, Godos J, Hébert JR, *et al.* (2018) Dietary inflammatory index and cardiovascular risk and mortality—a meta-analysis. *Nutrients* **10**, E200.
- García-Arellano A, Ramallal R, Ruiz-Canela M, *et al.* (2015) Dietary inflammatory index and incidence of cardiovascular disease in the PREDIMED Study. *Nutrients* **7**, 4124–4138.
- Hayden KM, Beavers DP, Steck SE, *et al.* (2017) The association between an inflammatory diet and global cognitive function and incident dementia in older women: the Women’s Health Initiative Memory Study. *Alzheimers Dement* **13**, 1187–1196.
- Shivappa N, Blair CK, Prizment AE, *et al.* (2016) Association between inflammatory potential of diet and mortality in the Iowa Women’s Health study. *Eur J Nutr* **55**, 1491–1502.
- nippon.com (2019) Middle-Aged Japanese Men and Their Expectations of Homemade Meals. <https://www.nippon.com/en/japan-data/h00499/middle-aged-japanese-men-and-their-expectations-of-homemade-meals.html> (accessed February 2022).
- Kondo K, Rosenberg M & Organization WH (2018) *Advancing Universal Health Coverage through Knowledge Translation for*



- Healthy Ageing: Lessons Learnt from the Japan Gerontological Evaluation Study*. Geneva: World Health Organization.
29. Hikichi H, Aida J, Tsuboya T, *et al.* (2016) Can community social cohesion prevent posttraumatic stress disorder in the aftermath of a disaster? A natural experiment from the 2011 Tohoku earthquake and tsunami. *Am J Epidemiol* **183**, 902–910.
  30. Sasaki S, Yanagibori R & Amano K (1998) Self-administered diet history questionnaire developed for health education: a relative validation of the test-version by comparison with 3-day diet record in women. *J Epidemiol* **8**, 203–215.
  31. Kobayashi S, Murakami K, Sasaki S, *et al.* (2011) Comparison of relative validity of food group intakes estimated by comprehensive and brief-type self-administered diet history questionnaires against 16 d dietary records in Japanese adults. *Public Health Nutr* **14**, 1200–1211.
  32. Kobayashi S, Honda S, Murakami K, *et al.* (2012) Both comprehensive and brief self-administered diet history questionnaires satisfactorily rank nutrient intakes in Japanese adults. *J Epidemiol* **22**, 151–159.
  33. Yatsuya H, Ohwaki A, Tamakoshi K, *et al.* (2003) Reproducibility and validity of a simple checklist-type questionnaire for food intake and dietary behavior. *J Epidemiol* **13**, 235–245.
  34. National Institute of Health and Nutrition & Department of Nutritional Epidemiology (2010) Dietary Reference Intakes for Japanese. [https://www.nibiohn.go.jp/en/files/Section\\_of\\_the\\_Dietary\\_Reference\\_Intakes/dris2010\\_eng.pdf](https://www.nibiohn.go.jp/en/files/Section_of_the_Dietary_Reference_Intakes/dris2010_eng.pdf) (accessed May 2022).
  35. Sheikh JI & Yesavage JA (1986) Geriatric Depression Scale (GDS): recent evidence and development of a shorter version. *Clin Gerontologist: J Aging Mental Health* **5**, 165–173.
  36. Niino N (1991) A Japanese translation of the Geriatric Depression Scale. *Clin Gerontol* **10**, 85–87.
  37. Sugishita K, Sugishita M, Hemmi I, *et al.* (2017) A validity and reliability study of the Japanese version of the geriatric depression scale 15 (GDS-15-J). *Clin Gerontol* **40**, 233–240.
  38. Fujii S, Kato H & Maeda K (2008) A simple interview-format screening measure for disaster mental health: an instrument newly developed after the 1995 Great Hanshin Earthquake in Japan—the Screening Questionnaire for Disaster Mental Health (SQD). *Kobe J Med Sci* **53**(6), 375–385.
  39. Shivappa N, Steck SE, Hurley TG, *et al.* (2014) Designing and developing a literature-derived, population-based dietary inflammatory index. *Public Health Nutr* **17**, 1689–1696.
  40. Shivappa N, Stubbs B, Hébert JR, *et al.* (2018) The relationship between the dietary inflammatory index and incident frailty: a longitudinal cohort study. *J Am Med Dir Assoc* **19**, 77–82.
  41. Sterne JAC, White IR, Carlin JB, *et al.* (2009) Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* **338**, b2393.
  42. Shiba K, Hikichi H, Aida J, *et al.* (2019) Long-term associations between disaster experiences and cardiometabolic risk: a natural experiment from the 2011 Great East Japan Earthquake and Tsunami. *Am J Epidemiol* **188**, 1109–1119.
  43. Khachadourian V (2019) *Effect of Earthquake-Related Losses and Post-Earthquake Events on Morbidity and Mortality: Causal Mediation Analysis of the Prospective Cohort Data of the 1988 Earthquake Survivors in Armenia*. Los Angeles, CA: UCLA.
  44. Stafford M, Cummins S, Macintyre S, *et al.* (2005) Gender differences in the associations between health and neighbourhood environment. *Soc Sci Med* **60**, 1681–1692.
  45. Wang MC, Kim S, Gonzalez AA, *et al.* (2007) Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. *J Epidemiol Community Health* **61**, 491–498.
  46. Tolin DF & Foa EB (2006) Sex differences in trauma and posttraumatic stress disorder: a quantitative review of 25 years of research. *Psychol Bull* **132**, 959–992.
  47. Yazawa A, Aida J, Kondo K, *et al.* (2022) Gender differences in risk of posttraumatic stress symptoms after disaster among older people: differential exposure or differential vulnerability? *J Affect Disord* **297**, 447–454.
  48. Péneau S, Ménard E, Méjean C, *et al.* (2013) Sex and dieting modify the association between emotional eating and weight status. *Am J Clin Nutr* **97**, 1307–1313.
  49. Camilleri GM, Méjean C, Kesse-Guyot E, *et al.* (2014) The associations between emotional eating and consumption of energy-dense snack foods are modified by sex and depressive symptomatology. *J Nutr* **144**, 1264–1273.
  50. Kontinen H, Männistö S, Sarlio-Lähteenkorva S, *et al.* (2010) Emotional eating, depressive symptoms and self-reported food consumption. A population-based study. *Appetite* **54**, 473–479.
  51. Crawford GB, Khedkar A, Flaws JA, *et al.* (2011) Depressive symptoms and self-reported fast-food intake in midlife women. *Prev Med* **52**, 254–257.
  52. Jeffery RW, Linde JA, Simon GE, *et al.* (2009) Reported food choices in older women in relation to body mass index and depressive symptoms. *Appetite* **52**, 238–240.
  53. Phillips CM, Shivappa N, Hébert JR, *et al.* (2018) Dietary inflammatory index and mental health: a cross-sectional analysis of the relationship with depressive symptoms, anxiety and well-being in adults. *Clin Nutr* **37**, 1485–1491.
  54. O'Connor DB, Jones F, Conner M, *et al.* (2008) Effects of daily hassles and eating style on eating behavior. *Health Psychol* **27**, S20–S31.
  55. Zhang W, Ohira T, Abe M, *et al.* (2017) Evacuation after the Great East Japan Earthquake was associated with poor dietary intake: the Fukushima Health Management Survey. *J Epidemiol* **27**, 14–23.
  56. Noda N, Ogawa N, Kuji R, *et al.* (2016) *Dietary Changes Due to Relocation to Temporary Housing (in Japanese)*. Annual meeting of The Japan Society of Home Economics. Aichi, Japan. vol. 68, pp. 288.
  57. Shiba K, Kawahara T, Aida J, *et al.* (2021) Causal inference in studying the long-term health effects of disasters: challenges and potential solutions. *Am J Epidemiol* **190**, 1867–1881.
  58. Pilgrim A, Robinson S, Sayer AA, *et al.* (2015) An overview of appetite decline in older people. *Nurs Older People* **27**, 29–35.
  59. Fielding RA, Vellas B, Evans WJ, *et al.* (2011) Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. *J Am Med Dir Assoc* **12**, 249–256.
  60. Kotronia E, Brown H, Papacosta AO, *et al.* (2021) Poor oral health and the association with diet quality and intake in older people in two studies in the UK and USA. *Br J Nutr* **126**, 118–130.