BMJ Open

Reducing depressive symptoms after the Great East Japan Earthquake in older survivors through group exercise participation and regular walking: A prospective observational study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-013706
Article Type:	Research
Date Submitted by the Author:	02-Aug-2016
Complete List of Authors:	TSUJI, Taishi; Chiba University, Center for Preventive Medical Sciences; Sasaki, Yuri; Chiba University, Center for Preventive Medical Science Matsuyama, Yusuke; Tohoku University Graduate School of Dentistry, Department of International and Community Oral Health SATO, Yukihiro; Tohoku University Graduate School of Dentistry, Department of International and Community Oral Health Aida, Jun; Tohoku University Graduate School of Dentistry, International and Community Oral Health Kondo, Katsunori; Chiba University, Center for Preventive Medical Sciences Kawachi, Ichiro; Harvard School of Public Health, Department of Society Human Development and
Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine
Keywords:	older adults, natural disaster, geriatric depression scale, the JAGES project, multiple imputation

Reducing depressive symptoms after the Great East Japan Earthquake in older survivors through group exercise participation and regular walking: A prospective observational study

Taishi TSUJI,[1] Yuri SASAKI,[1] Yusuke MATSUYAMA,[2] Yukihiro SATO,[2] Jun AIDA,[2] Katsunori KONDO,[1,3] Ichiro KAWACHI.[4]

1 Center for Preventive Medical Sciences, Chiba University, Chiba, Chiba, Japan.

2 Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan.

3 Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, Obu, Aichi, Japan.

4 Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA.

Corresponding author:

Taishi Tsuji

Center for Preventive Medical Sciences, Chiba University

1-8-1 Inohana, Chuo Ward, Chiba City, Chiba 260-8670 Japan

E-mail: tsuji.t@chiba-u.jp

Tel. +81.43.226.2803

Fax +81.43.226.2018

Word count: 2,944 words

ABSTRACT

Objectives Survivors of the 2011 Great East Japan Earthquake have an increased risk of depression. We sought to examine whether participation in group exercise and regular walking could mitigate the risk of depression among older survivors.

Design Prospective observational study.

Setting Our baseline survey was conducted in August 2010, approximately seven months prior to the Great East Japan Earthquake and tsunami, among people aged 65 or older residing in Iwanuma City, Japan, which suffered significant damage in the disaster. A three-year follow-up survey was conducted in 2013.

Participants 3,567 older survivors responded to the questionnaires pre- and post-disaster.

Primary outcome measures Change in depressive symptoms was assessed using the 15-item geriatric depression scale (GDS).

Results From pre- to post-disaster, the mean change in GDS score increased by 0.1 point (95% CI: −0.003-0.207). During the same interval, the frequency of group exercise participation and daily walking time also increased by 1.9 days/year, and 1.3 min/day, respectively. After adjusting for all covariates, including personal experiences of disaster, increases in the frequency of group exercise participation (B = −0.155, 95% CI: −0.254-−0.056, P = 0.002) and daily walking time (B = −0.136, 95% CI: −0.241-−0.031, P = 0.011) were associated with lower GDS scores. Interactions between housing damage and change in group exercise participation (B = 0.102, 95% CI: −0.001-0.204, P = 0.052) and change in walking habit (B = 0.089, 95% CI: −0.015-0.194, P = 0.095) were marginally significant, meaning that the protective effects tended to be attenuated among survivors reporting more extensive housing damage.

Conclusion Participation in group exercises or regular walking may reduce the risk of depression among older survivors who have experienced natural disaster.

Keywords: older adults, natural disaster, geriatric depression scale, the JAGES project, multiple imputation

Strengths and limitations of this study

- The strength of this study is the unprecedented and fortuitous availability of information pre-dating the disaster.
- The findings are available for the prevention of mental health problems from a public health intervention perspective in future serious natural disasters.
- We cannot exclude the possibility of simultaneous changes in exercise patterns and depressive symptoms happening during the course of follow-up.

INTRODUCTION

The frequency of natural disasters such as hurricanes, floods, and earthquakes has been increasing worldwide.[1] The experience of disaster presents a significant burden on the mental health of survivors.[2-4] Depression in older adults is strongly associated with being house-bound,[5] which may lead to a decline in physical and cognitive function and eventually to premature death.[6] To clarify the factors that contribute to mental health recovery after a disaster, several post-disaster surveys have been previously conducted.[7-9] However, these studies have relied upon survivors' recollection of their pre-disaster mental health status, potentially contributing to recall bias, i.e., the experience of disaster can color the respondents' assessment of their *status ex ante*. Clearly, it would be desirable to have pre-disaster information on survivors in order to avoid information bias.[10] To the best of our knowledge only two studies examining mental health status prior to disaster events have been conducted.[11, 12] Both studies suggested that major disaster was associated with an increase in the risk for common mental health disorders independently of previous mental health status and other potentially confounding factors. Little evidence, however, is available for the prevention of mental health problems from a public health intervention perspective.

Physical activity, which is a modifiable behavior, has the benefit of preventing or alleviating depressive symptoms in older adults.[13, 14] It has also been found that regular walking is by far the most prevalent physical activity in older adults[15] and has protective effects for depression.[16, 17] Participation in group exercises may be particularly effective for mental health promotion in the elderly by enhancing social participation in addition to physical activity.[18, 19] However, it is unclear whether the same benefits can be also obtained following the experience of natural disaster.

Following the Great East Japan Earthquake on March 11, 2011, various health promotion interventions -- including group exercise programs for older adults -- were initiated in disaster-stricken areas to address the health needs of survivors.[20, 21] Tomata and

colleagues[21] reported that there was no significant psychological benefit from attending group exercises once a month among middle-aged and older survivors in disaster-stricken areas. Possible reasons for this null finding were insufficient exercise frequency and sampling bias,[21] as participants might have had good health, behavior, and awareness before the disaster and might not have suffered much damage as a result of the disaster.

The purpose of the present study was to examine whether participation in group exercise and regular walking could mitigate the risk of depression among older survivors of the Great East Japan Earthquake after taking account of pre-disaster mental health status. We hypothesized that participation in group exercises or regular walking may reduce the risk of depression among older survivors who have experienced natural disaster.

METHODS

Study design

Our longitudinal study was conducted in Iwanuma City, a coastal municipality in the Miyagi prefecture, Japan, located approximately 80 km west of the epicenter of the Great East Japan Earthquake that occurred on March 11, 2011. Iwanuma City (total population 44,000) suffered tremendous damage from the earthquake and tsunami: 180 people were killed,[22] and 48% (29 km^2) of the land was inundated by seawater.[23] Our study takes advantage of the coincidence that Iwanuma City happened to be one of the field sites of the Japan Gerontological Evaluation Study (JAGES) Project,[24, 25] a nationwide, ongoing prospective cohort study that commenced in 2010 to investigate the social and behavioral factors associated with healthy aging. As part of the baseline survey for the JAGES Project cohort, we conducted a census of all adults aged 65 years or older living in Iwanuma City in August 2010, seven months prior to the earthquake. A three-year follow-up survey was conducted in October 2013, two years and seven months after the earthquake. After sending the questionnaires to all older adults living in Iwanuma City in the follow-up survey, we visited all the residences to collect the completed questionnaires. The participant flow-chart is shown

on Figure 1.[26]

Study participants were selected for the Iwanuma Project based on the following inclusion criteria: respondents from both the 2010 and 2013 surveys who had no limitations in activities of daily living (ADL) (i.e., they could independently walk, bathe, and visit the toilet) at the baseline survey in 2010.

The Ethics Committee at the Graduate school of Medicine, Chiba University, approved the study protocol. All participants gave informed consent.

Measurements

Change in depressive symptoms

We assessed depressive symptoms using the 15-item GDS[27, 28] as a continuous variable in both 2010 and 2013. The score range is 0–15 and higher value means more serious depression. Change in depressive symptoms calculated by subtracting the score in 2010 from that in 2013.

Changes in group exercise participation and regular daily walking

In both pre-disaster and post-disaster surveys, we ascertained the frequency of group exercise participation (4 days/week or more, 2–3 days/week, once a week, 1–3 time(s)/month, a few times/year, or none), as well as regular daily walking behavior (less than 30, 30–59, 60–89, or 90 min/day or more). We converted those categories into continuous variables, 260, 130, 52, 24, 6, and 0 day(s)/year, respectively, for group exercise participation, and 15, 45, 75, and 105 min/day, respectively, for walking behavior. Changes in group exercise participation and regular daily walking were calculated by subtracting the frequency and the time measured in 2010 from those measured in 2013.

Covariates

Information on age and sex were derived from the public register. Comorbid disease status

(no disease versus one or more diseases) and educational attainment were self-reported at baseline. Changes in drinking habits, smoking, and job status before and after the disaster, and impaired ADL after the disaster were categorized according to the 2010 and 2013 surveys. As an index of the personal experience of disaster damage, we asked about housing damage (1 no damage, 2 some damage, 3 partial destruction, 4 almost destroyed or 5 complete destruction), as well as the death of family member(s), while changes in income were calculated by subtracting the figure reported in 2010 from that in 2013.

Statistical analyses

Because 2,003 (56.2%) respondents in the analytic panel sample (n = 3,567) had missing data for one or more items in the 2010 and/or 2013 surveys, we performed multiple imputation. We created 20 multiple imputed data sets which included all measurement variables using a multivariate normal imputation method under a missing at random assumption, and combined the estimated parameters using Rubin's combination methods.[29, 30]

We compared the respondents' characteristics between complete cases without functional disability at baseline (n = 1,502) versus those who had missing data and/or had functional disability at baseline (n = 2,065). Pearson's correlation coefficient (*r*) and one-way ANOVA were used to investigate the relationship of exposure with change in depressive symptoms. Multiple linear regression models were used to examine the association of change in group exercise participation/regular walking before and after the disaster with change in depressive symptoms. The following four models were constructed. Changes in frequency of group exercise participation and changes in daily walking time were converted into Z-scores and were included in crude model. In model 1, sex and age were added to crude model. In model 2 we added three sets of covariates: i) covariates evaluated only at baseline (disease status and educational attainment), ii) covariates measured in both the 2010 and the 2013 surveys (impaired ADL, changes in drinking habits and smoking habits, job status, and equivalent income), and iii) covariates ascertained just on the 2013 survey (housing damage and death of family members). Model 3 added interaction terms: change in group exercise participation ×

housing damage and change in walking habit × housing damage. We used STATA13/SE (StataCorp, College Station, Texas, USA) for all statistical analyses and multiple imputations with the statistical significance set at $p < .05$ and the marginal significance set at $p < .10$.

RESULTS

Table 1 shows the respondents' characteristics for both the complete case sample as well as the sample missing data and/or had functional disability at baseline. Although there were significant differences in two groups with respect to mean GDS, frequency of group exercise participation, and daily walking time, there were no significant differences between the groups in the *changes* in those variables. Participants who had missing data and/or had functional disability at baseline tended to be older, more likely to be female, with a higher prevalence of comorbidity, and lower educational attainment.

Table 1. Participants' characteristics and comparison between participants with and without missing data and/or functional disability at baseline

	Total (n = 3,567)			Complete cases without functional disability at baseline (n = 1,502)		Participants who had missing data and/or had functional disability at baseline (n = 2,065)			
	Number of valid responses	Mean/n	SD/%	Mean/n	SD/%	Number of valid responses	Mean/n	SD/%	*P*
***Geriatric Depression Scale**, score*									
Baseline	3,074	3.7	3.4	3.2	3.2	1,572	4.1	3.6	<0.001
Change	2,746	0.1	2.8	0.1	2.6	1,244	0.1	3.0	0.483
***Frequency of group exercise participation**, day(s)/year*									
Baseline	2,992	20.4	44.1	23.7	47.1	1,490	17.2	40.6	<0.001
Change	2,887	1.9	44.5	2.8	45.9	1,385	1.0	42.9	0.276
***Walking habit**, min/day*									
Baseline	3,395	45.7	30.5	49.2	30.5	1,893	42.9	30.3	<0.001
Change	3,351	1.3	30.7	2.0	30.0	1,849	0.7	31.2	0.236

***Age**, year*	3,567	73.6	6.3	71.8	5.6	2,065	75.0	6.4	<0.001
***Female**, n (%)*	3,567	2,015	56.5%	642	42.7%	2,065	1,373	66.5%	<0.001
***One or more disease(s)**, n (%)*	3,494	2,756	78.9%	1,120	74.6%	1,992	1,636	82.1%	<0.001
Educational attainment, year	3,429	11.5	2.3	12.1	2.2	1,927	11.0	2.3	<0.001
***Activities of daily living**, n (%)*	3,443					1,941			<0.001
Maintain		3,039	88.3%	1,441	95.9%		1,598	82.3%	
Impaired after the Earthquake		265	7.7%	61	4.1%		204	10.5%	
Disabled at baseline		139	4.0%	0	0.0%		139	7.2%	
***Change in drinking habit**, n (%)*	3,466					1,964			<0.001
Drink.→Drink.		1,031	29.7%	597	39.7%		434	22.1%	
Non→Drink.		74	2.1%	35	2.3%		39	2.0%	
Drink.→Non		240	6.9%	125	8.3%		115	5.9%	
Non→Non		2,121	61.2%	745	49.6%		1,376	70.1%	
***Change in smoking habit**, n (%)*	3,252					1,750			0.019
Non→Non		2,869	88.2%	1,300	86.6%		1,569	89.7%	
Smok.→Non		115	3.5%	57	3.8%		58	3.3%	
Non→Smok.		18	0.6%	7	0.5%		11	0.6%	
Smok.→Smok.		250	7.7%	138	9.2%		112	6.4%	

Change in job status, *n (%)*	3,057					1,555			<0.001
Working→Working		323	10.6%	200	13.3%		123	7.9%	
No→Working		89	2.9%	42	2.8%		47	3.0%	
Working→No		225	7.4%	125	8.3%		100	6.4%	
No→No		2,420	79.2%	1,135	75.6%		1,285	82.6%	
Housing damage, *n (%)*	3,466					1,964			0.001
No damage		1,423	41.1%	651	43.3%		772	39.3%	
Some damage		1,496	43.2%	658	43.8%		838	42.7%	
Partial destruction		257	7.4%	97	6.5%		160	8.1%	
Almost destruction		131	3.8%	45	3.0%		86	4.4%	
Complete destruction		159	4.6%	51	3.4%		108	5.5%	
Lost family member(s), *n (%)*	3,567	936	26.2%	383	25.5%	2,065	553	26.8%	0.391
Equivalent income, *thousand yen*									
Baseline	2,911	230.2	141.8	246.1	136.7	1,409	213.3	145.2	<0.001
Change	2,561	-10.4	122.8	-8.7	116.7	1,059	-12.7	131.1	0.421

SD: standard deviation.

Table 2 shows the relationship of change in depressive symptoms with exposure and covariates in the complete case sample without functional disability at baseline. Based on correlation analyses, more frequent participation in group exercise and longer daily walking time were associated with lower depressive symptoms. Participants who had ADL impairments, who changed their smoking habits, or suffered extensive housing damage were more vulnerable to develop depression.

Table 2. Relationship of exposure and covariate variables with change in Geriatric Depression Scale score (complete cases: n = 1,502)

	n	*r*	*P* (Pearson's correlation)
Change in group exercise participation	1,502	-0.070	0.007
Change in walking habit	1,502	-0.053	0.041
Age	1,502	0.076	0.003
Educational attainment	1,502	0.026	0.311
Change in equivalent income	1,502	-0.001	0.968

	n	Mean	SD	*P* (One-way ANOVA)
Sex				
Male	860	0.1	2.6	0.166
Female	642	0.0	2.6	
Disease status				
No disease	382	0.2	2.5	0.330
One or more disease(s)	1,120	0.0	2.7	
Activities of daily living				
Maintain	1,441	0.0	2.5	<0.001

Impaired after the Earthquake	61	1.9	3.7	
Change in drinking habit				
Drink.→Drink.	597	0.1	2.3	0.069
Non→Drink.	35	-0.7	2.8	
Drink.→Non	125	0.5	3.0	
Non→Non	745	0.0	2.8	
Change in smoking habit				
Non→Non	1,300	0.0	2.6	<0.001
Smok.→Non	57	1.6	3.0	
Non→Smok.	7	0.9	3.6	
Smok.→Smok.	138	-0.3	2.4	
Change in job status				
Working→Working	200	-0.3	2.2	0.180
No→Working	42	0.4	3.3	
Working→No	125	0.3	2.7	
No→No	1,135	0.1	2.6	
Housing damage				
No damage	651	-0.1	2.5	<0.001
Some damage	658	0.0	2.6	
Partial destruction	97	0.3	3.0	
Almost destruction	45	0.2	2.6	
Complete destruction	51	1.6	2.9	
Lost family member(s)				
No	1,119	0.0	2.6	0.557
Yes	383	0.1	2.6	

SD: standard deviation, ANOVA: analysis of variance.

Table 3 shows the results of the multiple linear regression models based on both the multiply imputed and complete data sets. In the results obtained using multiply imputed data sets,

significant predictors of lower depressive symptoms included: increases in the frequency of group exercise participation ($B = -0.155$, $t = -3.06$, $P = 0.002$) and daily walking time ($B = -0.136$, $t = -2.54$, $P = 0.011$), after adjusting for all covariates. These relationships were attenuated when using the complete case analysis. In the model incorporating interaction terms, the group exercise participation × housing damage interaction ($B = 0.102$, $t = 1.95$, $P = 0.052$) and the change in walking habit × housing damage interaction ($B = 0.089$, $t = 1.67$, $P = 0.095$) were marginally significant, meaning that the protective effects of group exercise participation and walking tended to be attenuated among survivors reporting more extensive housing damage.

Results of all regression models involving covariates are shown in Supplementary Tables 1 and 2.

Table 3. Multiple linear regression of changes in group exercise participation and walking habit (converted into Z-scores) with change in depressive symptoms by analyzing multiply imputed and complete data sets

	Multiply imputed data sets (n = 3,335-3,340)					Complete data set (n = 1,502)				
	B	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*
Crude model										
Change in group exercise participation	-0.193	-0.295	-0.091	-3.70	<0.001	-0.167	-0.309	-0.026	-2.33	0.020
Change in walking habit	-0.198	-0.303	-0.092	-3.68	<0.001	-0.127	-0.270	0.015	-1.75	0.080
Model 1										
Change in group exercise participation	-0.174	-0.275	-0.073	-3.37	0.001	-0.152	-0.290	-0.013	-2.14	0.032
Change in walking habit	-0.190	-0.295	-0.085	-3.56	<0.001	-0.117	-0.260	0.025	-1.62	0.105
Model 2										
Change in group exercise participation	-0.171	-0.271	-0.072	-3.37	0.001	-0.149	-0.282	-0.016	-2.20	0.028
Change in walking habit	-0.147	-0.251	-0.042	-2.76	0.006	-0.083	-0.225	0.060	-1.14	0.255
Model 3										
Change in group exercise participation	-0.155	-0.254	-0.056	-3.06	0.002	-0.100	-0.241	0.040	-1.40	0.162
Change in walking habit	-0.136	-0.241	-0.031	-2.54	0.011	-0.071	-0.213	0.072	-0.97	0.331
Change in group exercise participation x housing damage	0.102	-0.001	0.204	1.95	0.052	0.159	-0.030	0.349	1.65	0.099

Change in walking habit x housing damage	0.089	-0.015	0.194	1.67	0.095	0.113	-0.019	0.246	1.68	0.093

Z-scores of 1.0 mean 44.5 days/year in the change in frequency of group exercise participation and 30.7 mins/day in the change in daily walking time.

CI: confidence interval.

Model 1: crude model + age and sex

Model 2: model 1 + disease status, educational attainment, impaired ADL, changes in drinking habits, smoking habits, and job status, equivalent income, housing damage, and death of family members

Model 3: model 2 + interaction terms

DISCUSSION

To the best of our knowledge, this is the first study to explore the potential benefits of group exercise participation and regular walking on depressive symptoms following exposure to natural disaster in which information on mental health status was available pre-dating the event. We found evidence that both of group exercise participation and regular walking after a natural disaster may reduce the risk of depressive symptoms in older survivors and after adjusting for level of damage, including the death of a family member and the extent of destruction of their homes. However, these preventive effects tended to be attenuated among survivors who reported suffering more extensive damage to their homes from the earthquake and tsunami.

Although the mean change in the GDS score before and after the disaster was only +0.1 among all study participants, 15.3% of those without depression (GDS < 5) at the time of the baseline survey (n = 1,833) developed mild or more severe depressive symptoms (GDS ≥ 5) after the disaster (data not shown). This rate was higher compared to that of a previous study (11.8%)[24] on 37,193 community-dwelling older adults sampled from 24 municipalities in Japan, most of whom had not been directly affected by the disaster, with the same period, follow-up duration, and depressive symptom criteria as those in the present study. Consistent with previous research,[2] we confirmed that the disaster may have had an adverse impact on the psychological status of older adults living in disaster-stricken areas.

Group exercise participation has positive physical activity and social participation effects on mental health.[18] Systematic reviews have shown that physical activity has preventive effects on depression and alleviates depressive symptoms in older adults.[13, 14, 31] Furthermore, a group exercise review for adults and older adults indicated that participating in group exercise promotes mental health by inducing enjoyment, enhancing self-esteem, and buffering stress.[18] These positive feelings are significantly connected with and can lead to a reduction in depressive symptoms with a small to moderate effect size.[32, 33] Another

possible mediator between group exercise participation and depression prevention is receiving social support.[18, 19] In the present study, we did not find any significant relationship between social support and depressive symptoms, although we investigated models that included instrumental and emotional social support from friends or acquaintances before and after disasters (data was not shown). From these results, we can conclude that group exercise participation can relieve depressive feelings and has a preventive effect on depression in older survivors, even in the unusual situation following a natural disaster.

We found significant links between increasing in regular walking habits and alleviation of depressive symptoms in the present study. These results were consistent with previous observational studies under usual conditions; that is, not after a disaster.[16, 34] A ten-year prospective cohort study revealed that older women who walk for more than 40 min/day have a lower risk of major depressive disorders, and also showed a dose-response relationship between daily walking time and risk.[16] However, the relationship was weak for walking at an easy pace (<2 miles/h) and more significant for an average or more brisk pace (≥2 miles/h).[16] Several RCTs indicated that group walking at a brisk pace can relief depressive symptoms in older adults.[17, 35, 36] Walking may also be recommended to prevent depression in groups. The fact that we could neither investigate pace, intensity, or manner (individually or in a group), in the present study was a major limitation.

Further, it is worth noting that these preventive effects on depression may be present even if the extent of damage from the disaster (housing damage or death of a family member) is taken into account. To buffer the increased risk of depression resulting from each level of housing damage (B = 0.238, see Suppl. Table 1), participating in an exercise group approximately twice a week -- or daily walking of 60 mins/day -- was required. However, we also found marginally significant interactions between changes in group exercise participation, walking habits, and home damage, indicating that the protective effects of exercise tended to be attenuated among survivors reporting more extensive housing damage. Although the reason for this result remains a matter of speculation, survivors who suffered

extensive housing damage may have had to walk involuntarily rather than engaging in physical activity for leisure. These results suggest that substantial support (e.g., providing an attractive group walking program with longer duration and higher frequency) might be needed for survivors who lived in areas severely damaged by a disaster to bring the benefits of group exercise participation and regular walking.

The strength of the present study is the unprecedented and fortuitous availability of information pre-dating the disaster. However, several limitations need to be mentioned, first, in the results from the complete data without multiple imputations, no statistical significance was found for the changes in either group exercise participation or regular walking after adjusting for all covariates. The possible reasons for these results were that the statistical power might have failed and the results may have been biased because 23% of the panel sample had missing GDS data in the 2010 and/or 2013 surveys. Second, the type and intensity of the group exercises in which participants took part was not investigated. Therefore, we could not distinguish the causes of the positive relationship between group exercise participation and the prevention of depressive symptoms between physical activity itself and group participation. Thirdly, and most importantly, we cannot exclude the possibility of simultaneous changes in exercise patterns & depressive symptoms happening during the course of follow-up. Thus, even though our analyses looked at changes in exercise predicting changes in depressive symptoms (first differences analysis), we cannot exclude the possibility that people stopped exercising because they felt depressed, or that they started to exercise because they felt well.

We conclude that increases in frequency of participating in group exercises and daily walking time after a natural disaster may alleviate depressive symptoms after a disaster in older survivors. These effects could be expected even after adjusting for the suffering resulting from serious damage, such as the death of a family member or the destruction of the primary residence. Giving older survivors the opportunity and environment for group exercise participation and walking in areas affected by the Great East Japan Earthquake and in future

serious natural disasters could be an effective support mechanism for depression prevention.

Acknowledgments

We appreciate the support and cooperation of the Iwanuma Mayor's office, and the staff of the Health and Welfare of Iwanuma City government. This study used data from the Japan Gerontological Evaluation Study (JAGES) as one of their research projects.

Footnotes

Contributors

TT: conception, design, analysis and interpretation of the data, and writing the article; YSas, YM, and YSat: conception, design, and critical revision of the article; JA: conception, design, data collection, and critical revision of the article; KK: conception, design, critical revision of the article, and principal investigator for the JAGES project; and IK: conception, design, critical revision of the article, and principal investigator for the Iwanuma project.

Funding

This work was supported by a grant from the Department of Health and Human Services, National Institute of Health, National Institute on Aging (Research Grant Number 1R01AG042463-01A1), Grant-in-Aid for Scientific Research (KAKENHI) (No. 22592327, 22390400, 23243070, 24390469) from the Japan Society for the Promotion of Science, and Health Labor Sciences Research Grant (No. 24140701) from the Japanese Ministry of Health, Labor and Welfare. The funding sources had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests

None declared.

Data sharing statement

No additional data are available.

References

1. Center for Research on the Epidemiology of Disasters. EM-DAT: The International Disaster Database. Secondary EM-DAT: The International Disaster Database 2014. http://www.emdat.be/.
2. Matsubara C, Murakami H, Imai K, et al. Prevalence and risk factors for depressive reaction among resident survivors after the tsunami following the Great East Japan Earthquake, March 11, 2011. *PLoS One* 2014;9:e109240.
3. Yokoyama Y, Otsuka K, Kawakami N, et al. Mental health and related factors after the Great East Japan earthquake and tsunami. *PLoS One* 2014;9:e102497.
4. Suzuki Y, Tsutsumi A, Fukasawa M, et al. Prevalence of mental disorders and suicidal thoughts among community-dwelling elderly adults 3 years after the niigata-chuetsu earthquake. *J Epidemiol* 2011;21:144-50.
5. Choi NG, McDougall GJ. Comparison of depressive symptoms between homebound older adults and ambulatory older adults. *Aging Ment Health* 2007;11:310-22.
6. Fiske A, Wetherell JL, Gatz M. Depression in older adults. *Annu Rev Clin Psychol* 2009;5:363-89.
7. Ali M, Farooq N, Bhatti MA, et al. Assessment of prevalence and determinants of posttraumatic stress disorder in survivors of earthquake in Pakistan using Davidson Trauma Scale. *J Affect Disord* 2012;136:238-43.
8. Beaudoin CE. News, social capital and health in the context of Katrina. *J Health Care Poor Underserved* 2007;18:418-30.
9. Wind TR, Komproe IH. The mechanisms that associate community social capital with post-disaster mental health: a multilevel model. *Soc Sci Med* 2012;75:1715-20.
10. Buttenheim A. Impact evaluation in the post-disaster setting: a case study of the 2005 Pakistan earthquake. *J Dev Effect* 2010;2:197-227.
11. Fergusson DM, Horwood LJ, Boden JM, et al. Impact of a major disaster on the mental health of a well-studied cohort. *JAMA Psychiatry* 2014;71:1025-31.
12. Arnberg FK, Gudmundsdottir R, Butwicka A, et al. Psychiatric disorders and suicide

attempts in Swedish survivors of the 2004 southeast Asia tsunami: a 5 year matched cohort study. *Lancet Psychiatry* 2015;2:817-24.

13. Blake H, Mo P, Malik S, et al. How effective are physical activity interventions for alleviating depressive symptoms in older people? A systematic review. *Clin Rehabil* 2009;23:873-87.
14. Bridle C, Spanjers K, Patel S, et al. Effect of exercise on depression severity in older people: systematic review and meta-analysis of randomised controlled trials. *Br J Psychiatry* 2012;201:180-5.
15. Yusuf HR, Croft JB, Giles WH, et al. Leisure-time physical activity among older adults. United States, 1990. *Arch Intern Med* 1996;156:1321-6.
16. Lucas M, Mekary R, Pan A, et al. Relation between clinical depression risk and physical activity and time spent watching television in older women: a 10-year prospective follow-up study. *Am J Epidemiol* 2011;174:1017-27.
17. Bernard P, Ninot G, Bernard PL, et al. Effects of a six-month walking intervention on depression in inactive post-menopausal women: a randomized controlled trial. *Aging Ment Health* 2015;19:485-92.
18. Kanamori S, Takamiya T, Inoue S. Group exercise for adults and elderly: Determinants of participation in group exercise and its associations with health outcome. *J Phys Fitness Sports Med* 2015;4:315-20.
19. Street G, James R, Cutt H. The relationship between organised physical recreation and mental health. *Health Promot J Austr* 2007;18:236-9.
20. Japan Health Promotion Fitness Foundation. Survey research on physical/psychological support activities through exercise and sports and their utilization method in affected areas of The Great East Japan Earthquake, 2012.
21. Tomata Y, Sato N, Kogure M, et al. Health effects of interventions to promote physical activity in survivors of the 2011 Great East Japan Earthquake. A longitudinal study. *Nihon Koshu Eisei Zasshi* 2015;62:66-72.
22. Ishigaki A, Higashi H, Sakamoto T, et al. The Great East-Japan Earthquake and devastating tsunami: an update and lessons from the past Great Earthquakes in Japan

since 1923. *Tohoku J Exp Med* 2013;229:287-99.

23. Geospatial Information Authority of Japan. Area of wetted surface from Tsunami disaster, 2011.
24. Tani Y, Sasaki Y, Haseda M, et al. Eating alone and depression in older men and women by cohabitation status: The JAGES longitudinal survey. *Age Ageing* 2015;44:1019-26.
25. Koyama S, Aida J, Kawachi I, et al. Social support improves mental health among the victims relocated to temporary housing following the Great East Japan Earthquake and Tsunami. *Tohoku J Exp Med* 2014;234:241-7.
26. Hikichi H, Aida J, Tsuboya T, at al. Can community social cohesion prevent PTSD in the aftermath of disaster? A natural experiment from the 2011 Tohoku earthquake and tsunami. *Am J Epidemiol* 2016;183:902-10.
27. Wada T, Ishine M, Kita T, et al. Depression screening of elderly community-dwelling Japanese. *J Am Geriatr Soc* 2003;51:1328-9.
28. Burke WJ, Roccaforte WH, Wengel SP. The short form of the Geriatric Depression Scale: a comparison with the 30-item form. *J Geriatr Psychiatry Neurol* 1991;4:173-8.
29. Rubin DB. *Multiple imputation for nonresponse in surveys*. Hoboken, NJ: Wiley-Interscience, 2004.
30. Carpenter JR, Kenward MG. *Multiple imputation and its application*. Hoboken, NJ: John Wiley & Sons, 2013.
31. Mammen G, Faulkner G. Physical activity and the prevention of depression: a systematic review of prospective studies. *Am J Prev Med* 2013;45:649-57.
32. Bolier L, Haverman M, Westerhof GJ, et al. Positive psychology interventions: a meta-analysis of randomized controlled studies. *BMC public health* 2013;13:119.
33. Proyer RT, Gander F, Wellenzohn S, et al. Positive psychology interventions in people aged 50-79 years: long-term effects of placebo-controlled online interventions on well-being and depression. *Aging Ment Health* 2014;18:997-1005.
34. Julien D, Gauvin L, Richard L, et al. The role of social participation and walking in depression among older adults: results from the VoisiNuAge study. *Can J Aging* 2013;32:1-12.

35. Gusi N, Reyes MC, Gonzalez-Guerrero JL, et al. Cost-utility of a walking programme for moderately depressed, obese, or overweight elderly women in primary care: a randomised controlled trial. *BMC public health* 2008;8:231.

36. Robertson R, Robertson A, Jepson R, et al. Walking for depression or depressive symptoms: A systematic review and meta-analysis. *Ment Health Phys Act* 2012;5:66-75.

Figure legends:

Figure 1. Participants flow in the Iwanuma Project and in the present study for with and without multiple imputation analysis.

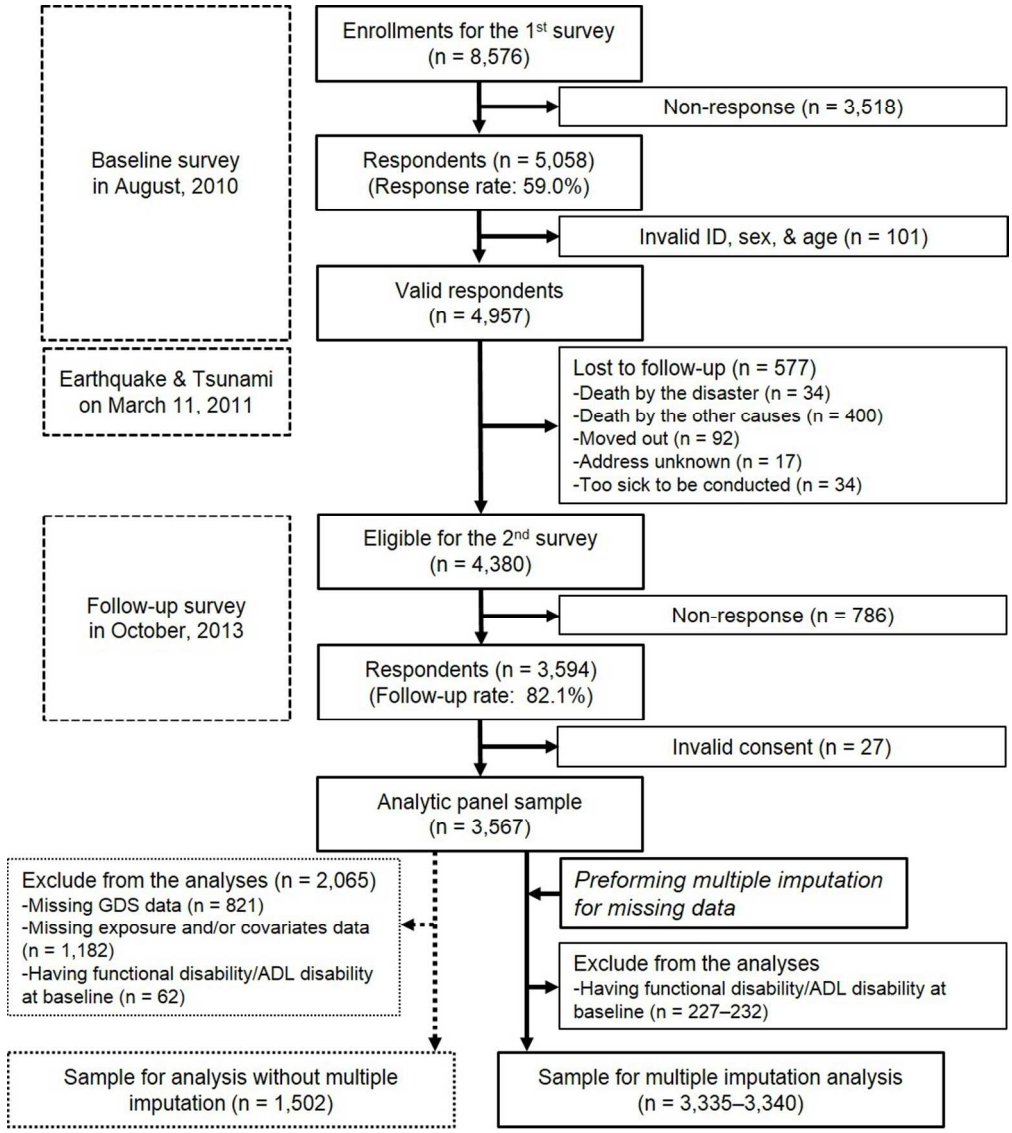

Figure 1. Participants flow in the Iwanuma Project and in the present study for with and without multiple imputation analysis

184x207mm (150 x 150 DPI)

Supplementary Table 1. Multiple linear regression of changes in group exercise participation and walking habit with change in depressive symptoms by analyzing multiply imputed data sets. (n = 3,335-3,340)

	Crude model					Model 1					Model 2					Model 3				
	B	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*
Change in group exercise participation (Z-scores of 1.0 = 44.5 days/year)	-0.193	-0.295	-0.091	-3.70	<0.001	-0.174	-0.275	-0.073	-3.37	0.001	-0.171	-0.271	-0.072	-3.37	0.001	-0.155	-0.254	-0.056	-3.06	0.002
Change in walking habit (Z-scores of 1.0 = 30.7 mins/day)	-0.198	-0.303	-0.092	-3.68	<0.001	-0.190	-0.295	-0.085	-3.56	<0.001	-0.147	-0.251	-0.042	-2.76	0.006	-0.136	-0.241	-0.031	-2.54	0.011
Age (year)						0.033	0.017	0.050	3.92	<0.001	0.023	0.004	0.041	2.43	0.015	0.022	0.004	0.041	2.40	0.017
Sex (1 men, 2 women)						-0.129	-0.324	0.066	-1.30	0.194	-0.151	-0.401	0.100	-1.18	0.237	-0.152	-0.402	0.098	-1.19	0.234
Disease status (0 no, 1 one or more)											-0.195	-0.420	0.031	-1.69	0.092	-0.197	-0.423	0.028	-1.71	0.087
Educational attainment (year)											0.056	0.010	0.101	2.38	0.018	0.056	0.010	0.102	2.40	0.016
Impaired ADL (0 no, 1 impaired)											1.300	0.740	1.860	4.55	<0.001	1.316	0.756	1.877	4.61	<0.001
Changes in drinking habits																				
Non→Drink.											-0.576	-1.285	0.133	-1.59	0.111	-0.586	-1.292	0.120	-1.63	0.104
Drink.→Non											0.248	-0.181	0.677	1.13	0.258	0.241	-0.187	0.669	1.10	0.270
Non→Non											0.018	-0.241	0.276	0.13	0.894	0.012	-0.245	0.269	0.09	0.928
Changes in smoking habits																				
Smoke.→Non											0.968	0.386	1.551	3.26	0.001	0.957	0.378	1.535	3.24	0.001
Non→Smoke.											1.247	-0.256	2.749	1.63	0.104	1.215	-0.291	2.722	1.58	0.114
Smoke.→Smoke.											-0.294	-0.657	0.069	-1.59	0.112	-0.291	-0.652	0.071	-1.58	0.115
Changes in job status																				
No→Working											0.291	-0.397	0.980	0.83	0.407	0.304	-0.380	0.989	0.87	0.384
Working→No											0.565	0.090	1.040	2.33	0.020	0.570	0.095	1.044	2.36	0.019
No→No											0.287	-0.012	0.586	1.88	0.060	0.290	-0.009	0.590	1.90	0.057
Housing damage (1 no damage → 5 complete destruction)											0.242	0.133	0.352	4.34	<0.001	0.238	0.129	0.347	4.29	<0.001
Lost family member(s) (0 no, 1 yes)											0.079	-0.147	0.304	0.68	0.494	0.088	-0.137	0.314	0.77	0.443
Changes in equivalent income (yen)											-0.001	-0.002	0.000	-1.00	0.319	0.000	-0.001	0.001	-0.99	0.326
Interaction																				
Change in exercise x housing damage																0.102	-0.001	0.204	1.95	0.052
Change in walking time x housing damage																0.089	-0.015	0.194	1.67	0.095

CI: confidence interval.

Supplementary Table 2. Multiple linear regression of changes in group exercise participation and walking habit with change in depressive symptoms by analyzing complete data set. (n = 1,502)

	Crude model					Model 1					Model 2					Model 3				
	B	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*	*B*	95% CI		*t*	*P*
Change in group exercise participation (Z-scores of 1.0 = 44.5 days/year)	-0.167	-0.309	-0.026	-2.33	0.020	-0.152	-0.290	-0.013	-2.14	0.032	-0.149	-0.282	-0.016	-2.20	0.028	-0.100	-0.241	0.040	-1.40	0.162
Change in walking habit (Z-scores of 1.0 = 30.7 mins/day)	-0.127	-0.270	0.015	-1.75	0.080	-0.117	-0.260	0.025	-1.62	0.105	-0.083	-0.225	0.060	-1.14	0.255	-0.071	-0.213	0.072	-0.97	0.331
Age (year)						0.033	0.009	0.057	2.66	0.008	0.026	0.000	0.052	1.95	0.051	0.025	-0.001	0.051	1.87	0.062
Sex (1 men, 2 women)						-0.152	-0.416	0.113	-1.12	0.262	-0.064	-0.403	0.276	-0.37	0.713	-0.070	-0.409	0.269	-0.41	0.685
Disease status (0 no, 1 one or more)											-0.238	-0.538	0.062	-1.55	0.120	-0.246	-0.547	0.054	-1.61	0.108
Educational attainment (year)											0.067	0.000	0.134	1.96	0.050	0.071	0.004	0.139	2.06	0.039
Impaired ADL (0 no, 1 impaired)											1.575	0.602	2.548	3.18	0.002	1.583	0.617	2.548	3.22	0.001
Changes in drinking habits																				
Non→Drink.											-0.639	-1.553	0.275	-1.37	0.171	-0.621	-1.528	0.287	-1.34	0.180
Drink.→Non											0.215	-0.338	0.768	0.76	0.446	0.201	-0.352	0.754	0.71	0.475
Non→Non											-0.149	-0.483	0.185	-0.87	0.382	-0.143	-0.478	0.192	-0.84	0.403
Changes in smoking habits																				
Smoke.→Non											1.414	0.687	2.140	3.82	<0.001	1.400	0.685	2.115	3.84	<0.001
Non→Smoke.											0.773	-1.648	3.195	0.63	0.531	0.743	-1.667	3.153	0.60	0.545
Smoke.→Smoke.											-0.364	-0.820	0.092	-1.57	0.117	-0.362	-0.814	0.091	-1.57	0.117
Changes in job status																				
No→Working											0.714	-0.300	1.727	1.38	0.167	0.677	-0.337	1.691	1.31	0.191
Working→No											0.369	-0.171	0.910	1.34	0.181	0.372	-0.169	0.913	1.35	0.178
No→No											0.269	-0.084	0.623	1.49	0.136	0.266	-0.089	0.621	1.47	0.142
Housing damage (1 no damage → 5 complete destruction)											0.301	0.145	0.457	3.78	<0.001	0.298	0.142	0.454	3.74	<0.001
Lost family member(s) (0 no, 1 yes)											0.061	-0.247	0.370	0.39	0.697	0.072	-0.236	0.381	0.46	0.646
Changes in equivalent income (yen)											0.000	-0.001	0.001	0.06	0.956	0.000	-0.001	0.001	0.21	0.836
Interaction																				
Change in exercise x housing damage																0.159	-0.030	0.349	1.65	0.099
Change in walking time x housing damage																0.113	-0.019	0.246	1.68	0.093

CI: confidence interval.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	■(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		■(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	■ (P4L1-) Explain the scientific background and rationale for the investigation being reported
Objectives	3	■ (P5L7-) State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	■ (P5L15-) Present key elements of study design early in the paper
Setting	5	■ (P5L15-) Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	■ (P5L15-) (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(N/A) (*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	■ (P6L11-) Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	■ (P5L15- & P6L11-) For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	■ (P7L10-) Describe any efforts to address potential sources of bias
Study size	10	(N/A) Explain how the study size was arrived at
Quantitative variables	11	■ (P7L10-) Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	■ (P7L10-) (*a*) Describe all statistical methods, including those used to control for confounding
		(N/A) (*b*) Describe any methods used to examine subgroups and interactions
		■ (P7L10-) (*c*) Explain how missing data were addressed
		■ (Figure 1) (*d*) If applicable, explain how loss to follow-up was addressed
		(N/A) (*e*) Describe any sensitivity analyses
Results		
Participants	13*	■ (Figure 1) (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		■ (Figure 1) (b) Give reasons for non-participation at each stage
		■ (Figure 1) (c) Consider use of a flow diagram
Descriptive data	14*	■ (Table 1 & P8L7-) (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		■ (Table 1) (b) Indicate number of participants with missing data for each variable of interest
		■ (P5L26-) (c) Summarise follow-up time (eg, average and total amount)
Outcome data	15*	■ (Table 1) Report numbers of outcome events or summary measures over time
Main results	16	■ (Table 3) (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which

		confounders were adjusted for and why they were included
		(N/A) (*b*) Report category boundaries when continuous variables were categorized
		(N/A) (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	(N/A) Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	■ (P17L3-) Summarise key results with reference to study objectives
Limitations	19	■ (P19L8-) Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	■ (P17L13-) Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	■ (P19L17-) Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	■ (P20L16-) Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Reducing depressive symptoms after the Great East Japan Earthquake in older survivors through group exercise participation and regular walking: A prospective observational study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2016-013706.R1
Article Type:	Research
Date Submitted by the Author:	10-Jan-2017
Complete List of Authors:	TSUJI, Taishi; Chiba University, Center for Preventive Medical Sciences; Sasaki, Yuri; Chiba University, Center for Preventive Medical Science Matsuyama, Yusuke; Tohoku University Graduate School of Dentistry, Department of International and Community Oral Health SATO, Yukihiro; Tohoku University Graduate School of Dentistry, Department of International and Community Oral Health Aida, Jun; Tohoku University Graduate School of Dentistry, International and Community Oral Health Kondo, Katsunori; Chiba University, Center for Preventive Medical Sciences Kawachi, Ichiro; Harvard School of Public Health, Department of Society Human Development and
Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine
Keywords:	older adults, natural disaster, geriatric depression scale, the JAGES project, multiple imputation

Reducing depressive symptoms after the Great East Japan Earthquake in older survivors through group exercise participation and regular walking: A prospective observational study

Taishi TSUJI,[1] Yuri SASAKI,[1] Yusuke MATSUYAMA,[2] Yukihiro SATO,[2] Jun AIDA,[2] Katsunori KONDO,[1,3] Ichiro KAWACHI.[4]

1 Center for Preventive Medical Sciences, Chiba University, Chiba, Chiba, Japan.

2 Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Sendai, Miyagi, Japan.

3 Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, Obu, Aichi, Japan.

4 Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA.

Corresponding author:

Taishi Tsuji

Center for Preventive Medical Sciences, Chiba University

1-8-1 Inohana, Chuo Ward, Chiba City, Chiba 260-8670 Japan

E-mail: tsuji.t@chiba-u.jp

Tel. +81.43.226.2803

Fax +81.43.226.2018

Word count: 2,944 words

ABSTRACT

Objectives Survivors of the 2011 Great East Japan Earthquake have an increased risk of depressive symptoms. We sought to examine whether participation in group exercise and regular walking could mitigate the worsening of depressive symptoms among older survivors.

Design Prospective observational study.

Setting Our baseline survey was conducted in August 2010, approximately seven months prior to the Great East Japan Earthquake and tsunami, among people aged 65 or older residing in Iwanuma City, Japan, which suffered significant damage in the disaster. A three-year follow-up survey was conducted in 2013.

Participants 3,567 older survivors responded to the questionnaires pre- and post-disaster.

Primary outcome measures Change in depressive symptoms was assessed using the 15-item geriatric depression scale (GDS).

Results From pre- to post-disaster, the mean change in GDS score increased by 0.1 point (95% CI: −0.003-0.207). During the same interval, the frequency of group exercise participation and daily walking time also increased by 1.9 days/year, and 1.3 min/day, respectively. After adjusting for all covariates, including personal experiences of disaster, we found that increases in the frequency of group exercise participation ($B = -0.139$, $\beta = -0.049$, $P = 0.003$) and daily walking time ($B = -0.087$, $\beta = -0.034$, $P = 0.054$) were associated with lower GDS scores. Interactions between housing damage and changes in group exercise participation ($B = 0.103$, $\beta = 0.034$, $P = 0.063$) and changes in walking habit ($B = 0.095$, $\beta = 0.033$, $P = 0.070$) were marginally significant, meaning that the protective effects tended to be attenuated among survivors reporting more extensive housing damage.

Conclusion Participation in group exercises or regular walking may mitigate the worsening of depressive symptoms among older survivors who have experienced natural disaster.

Keywords: older adults, natural disaster, geriatric depression scale, the JAGES project, multiple imputation

Strengths and limitations of this study

- The strength of this study is the unprecedented and fortuitous availability of information pre-dating the disaster.
- The study design enabled us to effectively address the problem of recall bias that occurs in most studies conducted in postdisaster settings.
- Selection bias might have occurred because of the 59% response rate to the baseline survey.
- The measurements rely entirely on self-reported data.

INTRODUCTION

The frequency of natural disasters such as hurricanes, floods, and earthquakes has been increasing worldwide.[1] The experience of disaster presents a significant burden on the mental health of survivors.[2-4] Depression in older adults is strongly associated with being house-bound,[5] which may lead to a decline in physical and cognitive function and eventually to premature death.[6] To clarify the factors that contribute to mental health recovery after a disaster, several post-disaster surveys have been previously conducted.[7-9] However, these studies have relied upon survivors' recollection of their pre-disaster mental health status, potentially contributing to recall bias, i.e., the experience of disaster can color the respondents' assessment of their *status ex ante*. Clearly, it would be desirable to have pre-disaster information on survivors in order to avoid information bias.[10] To the best of our knowledge only two studies examining mental health status prior to disaster events have been conducted.[11, 12] Both studies suggested that major disaster was associated with an increase in the risk for common mental health disorders independently of previous mental health status and other potentially confounding factors. Furthermore, a previous study suggested that dwelling house damage caused by major disasters was associated with worsening depressive symptoms in older survivors.[13] Little evidence, however, is available for the prevention of mental health problems from a public health intervention perspective.

Physical activity, which is a modifiable behavior, has the benefit of preventing or alleviating depressive symptoms[14, 15] and of treating depression[16, 17] in older adults. It has also been found that regular walking is by far the most prevalent physical activity in older adults[18] and has protective effects for depression.[19, 20] Participation in group exercises may be particularly effective for mental health promotion in the elderly by enhancing social participation in addition to physical activity.[21, 22] However, it is unclear whether the same benefits can be also obtained following the experience of natural disaster.

Following the Great East Japan Earthquake on March 11, 2011, various health promotion

interventions -- including group exercise programs for older adults -- were initiated in disaster-stricken areas to address the health needs of survivors.[23, 24] Tomata and colleagues[24] reported that there was no significant psychological benefit from attending group exercises once a month among middle-aged and older survivors in disaster-stricken areas. Possible reasons for this null finding were insufficient exercise frequency and sampling bias,[24] as participants might have had good health, behavior, and awareness before the disaster and might not have suffered much damage as a result of the disaster.

The purpose of the present study was to examine whether participation in group exercise and regular walking could mitigate the worsening of depressive symptoms among older survivors of the Great East Japan Earthquake after taking into account pre-disaster mental health status. We hypothesized that participation in group exercises or regular walking may mitigate the worsening of depressive symptoms among older survivors who have experienced natural disaster. These associations, however, may differ according to the extent of damage caused by the disaster.

METHODS

Study design

Our longitudinal study was conducted in Iwanuma City, a coastal municipality in the Miyagi prefecture, Japan, located approximately 80 km west of the epicenter of the Great East Japan Earthquake that occurred on March 11, 2011. Iwanuma City (total population 44,000) suffered tremendous damage from the earthquake and tsunami: 180 people were killed,[25] and 48% (29 km^2) of the land was inundated by seawater.[26] Our study takes advantage of the coincidence that Iwanuma City happened to be one of the field sites of the Japan Gerontological Evaluation Study (JAGES) Project,[27, 28] a nationwide, ongoing prospective cohort study that commenced in 2010 to investigate the social and behavioral factors associated with healthy aging. As part of the baseline survey for the JAGES Project cohort, we conducted a census of all adults aged 65 years or older living in Iwanuma City in August

2010, seven months prior to the earthquake. A three-year follow-up survey was conducted in November 2013, two years and seven months after the earthquake. After sending the questionnaires to all older adults living in Iwanuma City in the follow-up survey, we visited all the residences to collect the completed questionnaires. The participant flow-chart is shown on Figure 1.[29]

Study participants were selected for the Iwanuma Project based on the following inclusion criteria: respondents from both the 2010 and 2013 surveys who had no limitations in activities of daily living (ADL) (i.e., they could independently walk, bathe, and visit the toilet) at the baseline survey in 2010.

The Ethics Committee at the Graduate school of Medicine, Chiba University, approved the study protocol. All participants gave informed consent.

Measurements

Change in depressive symptoms

We assessed depressive symptoms using the 15-item geriatric depression scale (GDS)[30, 31] as a continuous variable in both 2010 and 2013. The score range is 0–15 and higher value means greater severity of depressive symptoms. Change in depressive symptoms calculated by subtracting the score in 2010 from that in 2013.

Changes in group exercise participation and regular daily walking

In both pre-disaster and post-disaster surveys, we ascertained the frequency of group exercise participation (4 days/week or more, 2–3 days/week, once a week, 1–3 time(s)/month, a few times/year, or none), as well as regular daily walking behavior (less than 30, 30–59, 60–89, or 90 min/day or more). We converted those categories into continuous variables, 260, 130, 52, 24, 6, and 0 day(s)/year, respectively, for group exercise participation, and 15, 45, 75, and 105 min/day, respectively, for walking behavior. Changes in group exercise participation and regular daily walking were calculated by subtracting the frequency and the time measured in

2010 from those measured in 2013.

Covariates

Information on age and sex were derived from the public register. Psychological disorder, comorbid disease status other than psychological disorder (no disease versus one or more diseases) and educational attainment were self-reported at baseline. Changes in drinking habits, smoking, and job status before and after the disaster, and impaired ADL after the disaster were categorized according to the 2010 and 2013 surveys. Change in instrumental ADL (IADL) was calculated by subtracting the Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC)[32] score in 2010 from that in 2013. A lower value indicated a worsening ability to perform IADL. As an index of the personal experience of disaster damage, we asked about housing damage (1 no damage, 2 some damage, 3 partial destruction, 4 almost destroyed or 5 complete destruction), as well as the death of family member(s), while changes in income were calculated by subtracting the figure reported in 2010 from that in 2013.

Statistical analyses

Because 2,061 (57.8%) respondents in the analytic panel sample (n = 3,567) had missing data for one or more items in the 2010 and/or 2013 surveys, we performed multiple imputation. We created 20 multiple imputed data sets which included all measurement variables using a multivariate normal imputation method under a missing at random assumption, and combined the estimated parameters using Rubin's combination methods.[33, 34]

We compared the respondents' characteristics between complete cases without ADL impairments at baseline (n = 1,449) versus those who had missing data and/or had ADL impairments at baseline (n = 2,118). Pearson's correlation coefficient (*r*) and one-way ANOVA were used to investigate the relationship of exposure with change in depressive symptoms. Multiple linear regression models were used to examine the association of change in group exercise participation/regular walking before and after the disaster with change in

depressive symptoms. The following four models were constructed. Changes in frequency of group exercise participation and changes in daily walking time were converted into Z-scores and were included in crude model. In model 1, sex and age were added to crude model. In model 2 we added three sets of covariates: i) covariates evaluated only at baseline (disease status and educational attainment), ii) covariates measured in both the 2010 and the 2013 surveys (impaired ADL, changes in drinking habits and smoking habits, job status, equivalent income, and IADL score), and iii) covariates ascertained just on the 2013 survey (housing damage and death of family members). Model 3 added interaction terms: change in group exercise participation × housing damage and change in walking habit × housing damage. These models were also constructed in participants with GDS score < 5 (non-depressed) or ≥ 5 (depressed)[35] separately. We used STATA13/SE (StataCorp, College Station, Texas, USA) for all statistical analyses and multiple imputations with the statistical significance set at $P < .05$ and the marginal significance set at $P < .10$.

RESULTS

Table 1 shows the respondents' characteristics for both the complete case sample as well as the sample missing data and/or had ADL impairments at baseline. Although there were significant differences in two groups with respect to mean GDS, frequency of group exercise participation, and daily walking time, there were no significant differences between the groups in the *changes* in those variables. Participants who had missing data and/or had ADL impairments at baseline tended to be older, more likely to be female, with a higher prevalence of comorbidity, and lower educational attainment and IADL score.

Table 1. Participants' characteristics and comparison between participants with and without missing data and/or ADL impairments at baseline

	Total (n = 3,567)			Complete cases without ADL impairments at baseline (n = 1,449)		Participants who had missing data and/or had ADL impairments at baseline (n = 2,118)			
	Number of valid responses	Mean/n	SD/%	Mean/n	SD/%	Number of valid responses	Mean/n	SD/%	*P*
***Geriatric Depression Scale**, score*									
Baseline	3,074	3.7	3.4	3.1	3.1	1,625	4.1	3.6	<0.001
Change	2,746	0.1	2.8	0.1	2.6	1,297	0.1	3.0	0.407
***Frequency of group exercise participation**, day(s)/year*									
Baseline	2,992	20.4	44.1	24.3	47.6	1,543	16.9	40.2	<0.001
Change	2,887	1.9	44.5	3.0	46.4	1,438	0.8	42.4	0.203
***Walking habit**, min/day*									
Baseline	3,395	45.7	30.5	49.7	30.5	1,946	42.7	30.2	<0.001
Change	3,351	1.3	30.7	1.9	30.1	1,902	0.8	31.1	0.337

***Age**, year*	3,567	73.6	6.3	71.7	5.5	2,118	75.0	6.4	<0.001
***Female**, n (%)*	3,567	2,015	56.5%	622	42.9%	2,118	1,393	65.8%	<0.001
***Psychological disorder**, n (%)*	3,479	44	1.3%	8	0.6%	2,030	36	1.8%	0.001
***One or more disease(s)**, n (%)*	3,479	2,731	78.5%	1,078	74.4%	2,030	1,653	81.4%	<0.001
Educational attainment, year	3,429	11.5	2.3	12.1	2.2	1,980	11.1	2.3	<0.001
***Activities of daily living**, n (%)*	3,443					1,994			<0.001
Maintain		3,039	88.3%	1,394	96.2%		1,645	82.5%	
Impaired after the Earthquake		265	7.7%	55	3.8%		210	10.5%	
Disabled at baseline		139	4.0%	0	0.0%		139	7.0%	
***Change in drinking habit**, n (%)*	3,466					2,017			<0.001
Drink.→Drink.		1,031	29.7%	580	40.0%		451	22.4%	
Non→Drink.		74	2.1%	33	2.3%		41	2.0%	
Drink.→Non		240	6.9%	122	8.4%		118	5.9%	
Non→Non		2,121	61.2%	714	49.3%		1,407	69.8%	
***Change in smoking habit**, n (%)*	3,252					1,803			0.203
Non→Non		2,869	88.2%	1,261	87.0%		1,608	89.2%	
Smok.→Non		115	3.5%	55	3.8%		60	3.3%	
Non→Smok.		18	0.6%	7	0.5%		11	0.6%	

Smok.→Smok.		250	7.7%	126	8.7%		124	6.9%	
Change in job status, *n (%)*	3,057					1,608			<0.001
Working→Working		323	10.6%	196	13.5%		127	7.9%	
No→Working		89	2.9%	40	2.8%		49	3.0%	
Working→No		225	7.4%	118	8.1%		107	6.7%	
No→No		2,420	79.2%	1,095	75.6%		1,325	82.4%	
Dwelling house damage, *n (%)*	3,466					2,017			<0.001
No damage		1,423	41.1%	627	43.3%		796	39.5%	
Some damage		1,496	43.2%	640	44.2%		856	42.4%	
Partial destruction		257	7.4%	93	6.4%		164	8.1%	
Almost destruction		131	3.8%	42	2.9%		89	4.4%	
Complete destruction		159	4.6%	47	3.2%		112	5.6%	
Lost family member(s), *n (%)*	3,567	936	26.2%	370	25.5%	2,065	566	27.4%	0.428
Equivalent income, *ten thousand yen*									
Baseline	2,911	230.2	141.8	246.5	136.7	1,462	214.0	145.0	<0.001
Change	2,561	-10.4	122.8	-8.6	117.4	1,112	-12.6	129.6	0.413
IADL scale, *score*									
Baseline	3,336	11.6	2.3	12.1	1.6	1,887	11.3	2.7	<0.001

Change	3,180	-0.6	2.0	-0.4	1.6	1,731	-0.8	2.2	<.001

* other than psychological disorder.

SD: standard deviation, ADL: activities of daily living, IADL: instrumental activities of daily living.

Supplementary Table 1 shows the relationship of change in depressive symptoms with exposure and covariates in the complete case sample without ADL impairments at baseline. Based on correlation analyses, more frequent participation in group exercise was associated with lower depressive symptoms. Participants who had ADL impairments, who changed their smoking habits, or suffered extensive housing damage were more vulnerable to developing depressive symptoms.

Tables 2a and 2b show the results of the multiple linear regression models based on the multiply imputed data sets. Significant and marginally significant predictors of lower depressive symptoms included increases in the frequency of group exercise participation ($B = -0.139$, $\beta = -0.049$, $P = 0.003$) and daily walking time ($B = -0.087$, $\beta = -0.034$, $P = 0.054$), after adjusting for all covariates, respectively. In the model incorporating interaction terms, the group exercise participation × housing damage interaction ($B = 0.103$, $\beta = 0.034$, $P = 0.063$) and the change in walking habit × housing damage interaction ($B = 0.095$, $\beta = 0.033$, $P = 0.070$) were marginally significant, meaning that the protective effects of group exercise participation and walking tended to be attenuated among survivors reporting more extensive housing damage. Results of all regression models based on the complete data set are shown in Supplementary Table 2. These relationships were attenuated when using the complete case analysis. Supplementary Table 3 shows the results of the multiple linear regression models with (GDS ≥ 5) and without (GDS < 5) depressive symptoms at baseline. Large coefficients were generally observed in older adults with depressive symptoms compared to those without depressive symptoms at baseline, although these associations did not reach statistical significance after adjustment of covariates because of limited statistical power.

Table 2a. Multiple linear regression of changes in group exercise participation and walking habit (converted into Z-scores) with change in depressive symptoms by analyzing multiply imputed data sets (n = 3,335–3,339, crude model and model 1)

	Crude model					Model 1					
	B	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*
Change in group exercise participation *(44.5 days/year)*	-0.188	-0.290	-0.086	-0.061	-3.63	<0.001	-0.169	-0.270	-0.068	-0.055	-3.30	0.001
Change in walking habit *(30.7 mins/day)*	-0.199	-0.305	-0.094	-0.068	-3.72	<0.001	-0.192	-0.296	-0.087	-0.066	-3.60	<0.001
Age *(year)*							0.034	0.017	0.050	0.073	3.97	<0.001
Sex *(1 men, 2 women)*							-0.133	-0.328	0.062	-0.023	-1.33	0.183

CI: confidence interval.

Table 2b. Multiple linear regression of changes in group exercise participation and walking habit (converted into Z-scores) with change in depressive symptoms by analyzing multiply imputed data sets (n = 3,335–3,339, models 2 and 3)

	Model 2					Model 3					
	B	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*
Change in group exercise participation *(44.5 days/year)*	-0.156	-0.256	-0.057	-0.051	-3.07	0.002	-0.139	-0.239	-0.038	-0.049	-3.00	0.003
Change in walking habit *(30.7 mins/day)*	-0.098	-0.199	0.003	-0.034	-1.90	0.058	-0.087	-0.189	0.016	-0.034	-1.93	0.054

Age *(year)*	0.006	-0.013	0.024	0.012	0.59	0.558	0.005	-0.013	0.024	0.011	0.55	0.585
Sex *(1 men, 2 women)*	-0.119	-0.364	0.126	-0.020	-0.95	0.341	-0.119	-0.364	0.125	-0.020	-0.96	0.339
Psychological disorder *(0 no, 1 yes)*	-0.769	-2.194	0.655	-0.029	-1.06	0.290	-0.774	-2.199	0.651	-0.029	-1.06	0.287
Disease status *(0 no, 1 one or more)**	-0.203	-0.426	0.019	-0.029	-1.79	0.074	-0.207	-0.430	0.016	-0.029	-1.82	0.069
Educational attainment *(year)*	0.053	0.007	0.098	0.042	2.28	0.022	0.053	0.008	0.098	0.043	2.31	0.021
Impaired ADL *(0 no, 1 impaired)*	0.568	0.025	1.110	2.950	2.05	0.040	0.584	0.041	1.126	3.032	2.11	0.035
Changes in drinking habits												
Non→Drink.	-0.563	-1.236	0.111	-0.029	-1.64	0.101	-0.570	-1.238	0.098	-0.029	-1.67	0.095
Drink.→Non	0.213	-0.221	0.646	0.018	0.96	0.336	0.203	-0.229	0.635	0.018	0.92	0.357
Non→Non	-0.028	-0.281	0.225	-0.005	-0.22	0.827	-0.034	-0.286	0.219	-0.006	-0.26	0.793
Changes in smoking habits												
Smoke.→Non	0.841	0.285	1.396	0.051	2.97	0.003	0.826	0.274	1.378	0.050	2.93	0.003
Non→Smoke.	1.308	-0.185	2.801	0.035	1.72	0.086	1.267	-0.227	2.762	0.034	1.66	0.097
Smoke.→Smoke.	-0.308	-0.667	0.051	-0.027	-1.68	0.093	-0.304	-0.661	0.054	-0.027	-1.67	0.096
Changes in job status												
No→Working	0.284	-0.422	0.990	0.017	0.79	0.429	0.297	-0.403	0.997	0.018	0.83	0.405
Working→No	0.624	0.171	1.078	0.056	2.70	0.007	0.630	0.176	1.083	0.057	2.72	0.007
No→No	0.270	-0.027	0.566	0.037	1.79	0.074	0.274	-0.023	0.570	0.038	1.81	0.071
Dwelling house damage *(1 no damage → 5 complete destruction)*	0.212	0.105	0.319	0.074	3.90	<0.001	0.215	0.108	0.321	0.075	3.96	<0.001

Death of family member(s) *(0 no, 1 yes)*	0.118	-0.104	0.340	0.018	1.04	0.299	0.128	-0.095	0.350	0.019	1.13	0.260
Change in equivalent income *(million yen)*	-0.059	-0.145	0.027	-0.026	-1.36	0.176	-0.059	-0.144	0.027	-0.025	-1.35	0.179
Change in IADL *(score)*	-0.266	-0.337	-0.195	-0.192	-7.33	<0.001	-0.267	-0.338	-0.196	-0.193	-7.37	<0.001
Interaction												
Change in exercise x house damage							0.103	-0.006	0.213	0.034	1.86	0.063
Change in walking time x house damage							0.095	-0.008	0.198	0.033	1.81	0.070

* other than psychological disorder.

CI: confidence interval, ADL: activities of daily living, IADL: instrumental activities of daily living.

DISCUSSION

To the best of our knowledge, this is the first study to explore the potential benefits of group exercise participation and regular walking on depressive symptoms following exposure to natural disaster in which information on mental health status was available pre-dating the event. We found evidence that both of group exercise participation and regular walking after a natural disaster may reduce the risk of depressive symptoms in older survivors and after adjusting for level of damage, including the death of a family member and the extent of destruction of their homes. However, these preventive effects tended to be attenuated among survivors who reported suffering more extensive damage to their homes from the earthquake and tsunami.

Although the mean change in the GDS score before and after the disaster was only +0.1 among all study participants, 15.3% of those without depressive symptoms (GDS < 5) at the time of the baseline survey (n = 1,833) developed mild or more severe depressive symptoms (GDS ≥ 5) after the disaster (data not shown). This rate was higher compared to that of a previous study (11.8%)[27] on 37,193 community-dwelling older adults sampled from 24 municipalities in Japan, most of whom had not been directly affected by the disaster, with the same period, follow-up duration, and depressive symptom criteria as those in the present study. Consistent with previous research,[2] we confirmed that the disaster may have had an adverse impact on the psychological status of older adults living in disaster-stricken areas.

Group exercise participation has positive physical activity and social participation effects on mental health.[21] Systematic reviews have shown that physical activity has preventive and treatment effects on depression and alleviates depressive symptoms in older adults.[14-17, 36] Furthermore, a group exercise review for adults and older adults indicated that participating in group exercise promotes mental health by inducing enjoyment, enhancing self-esteem, and buffering stress.[21] These positive feelings are significantly connected with and can lead to a reduction in depressive symptoms with a small to moderate effect size.[37,

38] Another possible mediator between group exercise participation and depression prevention is receiving social support.[21, 22] In the present study, we did not find any significant relationship between social support and depressive symptoms, although we investigated models that included instrumental and emotional social support from friends or acquaintances before and after disasters (data was not shown). From these results, we can conclude that group exercise participation can relieve depressive feelings in older survivors, even in the unusual situation following a natural disaster.

We found marginally significant links between increasing in regular walking habits and alleviation of depressive symptoms in the present study. These results were consistent with previous observational studies under usual conditions; that is, not after a disaster.[19, 39] A ten-year prospective cohort study revealed that older women who walk for more than 40 min/day have a lower risk of major depressive disorders, and also showed a dose-response relationship between daily walking time and risk.[19] However, the relationship was weak for walking at an easy pace (<2 miles/h) and more significant for an average or more brisk pace (≥2 miles/h).[19] Several RCTs indicated that group walking at a brisk pace can relief depressive symptoms in older adults.[20, 40, 41] Walking may also be recommended to prevent depressive symptoms in groups. The fact that we could neither investigate pace, intensity, or manner (individually or in a group), in the present study was a major limitation.

Further, it is worth noting that these preventive effects on depressive symptoms may be present even if the extent of damage from the disaster (housing damage or death of a family member) is taken into account. To mitigate the worsening of depressive symptoms resulting from each level of housing damage (B = 0.215, see Table 2b), participating in an exercise group approximately 5 to 6 times per month -- or daily walking of 75 mins/day -- was required. In addition, an increasing frequency of participating in an exercise group once a week (= 52 days/year) was equivalent to +2.75 million yen (≈ 27.5 thousand dollars) of change in equivalent income, although this was not a statistically significant relevant factor. On the basis of the standardized β coefficients, the mitigational impact of change in group

exercise participation ($\beta = -0.049$) was comparable to the worsening impact of low educational attainment ($\beta = 0.043$), the interruption of smoking ($\beta = 0.050$), and the loss or interruption of a job ($\beta = 0.057$). However, we also found marginally significant interactions between changes in group exercise participation, walking habits, and home damage, indicating that the protective effects of exercise tended to be attenuated among survivors reporting more extensive housing damage. Although the reason for this result remains a matter of speculation, survivors who suffered extensive housing damage may have had to walk involuntarily rather than engaging in physical activity for leisure. These results suggest that substantial support (e.g., providing an attractive group walking program with longer duration and higher frequency) might be needed for survivors who lived in areas severely damaged by a disaster to bring the benefits of group exercise participation and regular walking.

The strength of the present study is the unprecedented and fortuitous availability of information pre-dating the disaster. However, several limitations need to be mentioned. Firstly, the measurements used in our analysis relied entirely upon self-reported data. Therefore, depressed subjects may recall their exercise differently from non-depressed subjects (information bias); in other words, depressed people may have under-reported their physical activity. Furthermore, our use of GDS may have led to an under-estimation of the impacts of group exercise participation and walking because the GDS omits neuro-vegetative symptoms (for which physical activity may be particularly effective). Secondly, physical activity was not assessed using a standardized questionnaire which is widely used and associated with sufficient validity and reliability. Furthermore, the type and intensity of the group exercises in which participants took part was not investigated. Therefore, we could not distinguish the causes of the positive relationship between group exercise participation and the prevention of depressive symptoms between physical activity itself and group participation. Self-paced intensity may increase the pleasure people experience when exercising, thereby improving adherence.[42] In a future study, we aim to objectively evaluate pace, intensity, style, and manner of physical activity to investigate the effects of

physical activity on mental health in older adults in a more precise manner, including dose-response relationships. Thirdly, excluding older adults who had ADL impairments at baseline from the present analyses may have led to the under-representation of those with physical illnesses and associated depressive symptoms. Fourthly, and most importantly, we cannot exclude the possibility of simultaneous changes in exercise patterns & depressive symptoms happening during the course of follow-up. Thus, even though our analyses looked at changes in exercise predicting changes in depressive symptoms (first differences analysis), we cannot exclude the possibility that people stopped exercising because they felt depressed, or that they started to exercise because they felt well.

We conclude that increases in frequency of participating in group exercises and daily walking time after a natural disaster may alleviate depressive symptoms after a disaster in older survivors. These effects could be expected even after adjusting for the suffering resulting from serious damage, such as the death of a family member or the destruction of the primary residence. Giving older survivors the opportunity and environment for group exercise participation and walking in areas affected by the Great East Japan Earthquake and in future serious natural disasters could be an effective support mechanism for prevention of depressive symptoms.

Acknowledgments

We appreciate the support and cooperation of the Iwanuma Mayor's office, and the staff of the Health and Welfare of Iwanuma City government. This study used data from the Japan Gerontological Evaluation Study (JAGES) as one of their research projects.

Footnotes

Contributors

TT: conception, design, analysis and interpretation of the data, and writing the article; YSas, YM, and YSat: conception, design, and critical revision of the article; JA: conception, design, data collection, and critical revision of the article; KK: conception, design, critical revision of

the article, and principal investigator for the JAGES project; and IK: conception, design, critical revision of the article, and principal investigator for the Iwanuma project.

Funding

This work was supported by a grant from the Department of Health and Human Services, National Institute of Health, National Institute on Aging (Research Grant Number 1R01AG042463-01A1), Grant-in-Aid for Scientific Research (KAKENHI) (No. 22592327, 22390400, 23243070, 24390469) from the Japan Society for the Promotion of Science, and Health Labor Sciences Research Grant (No. 24140701) from the Japanese Ministry of Health, Labor and Welfare. The funding sources had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests

None declared.

Data sharing statement

No additional data are available.

References

1. Center for Research on the Epidemiology of Disasters. EM-DAT: The International Disaster Database. Secondary EM-DAT: The International Disaster Database 2014. http://www.emdat.be/.
2. Matsubara C, Murakami H, Imai K, et al. Prevalence and risk factors for depressive reaction among resident survivors after the tsunami following the Great East Japan Earthquake, March 11, 2011. *PLoS One* 2014;9:e109240.
3. Yokoyama Y, Otsuka K, Kawakami N, et al. Mental health and related factors after the Great East Japan earthquake and tsunami. *PLoS One* 2014;9:e102497.
4. Suzuki Y, Tsutsumi A, Fukasawa M, et al. Prevalence of mental disorders and suicidal thoughts among community-dwelling elderly adults 3 years after the niigata-chuetsu

earthquake. *J Epidemiol* 2011;21:144-50.

5. Choi NG, McDougall GJ. Comparison of depressive symptoms between homebound older adults and ambulatory older adults. *Aging Ment Health* 2007;11:310-22.
6. Fiske A, Wetherell JL, Gatz M. Depression in older adults. *Annu Rev Clin Psychol* 2009;5:363-89.
7. Ali M, Farooq N, Bhatti MA, et al. Assessment of prevalence and determinants of posttraumatic stress disorder in survivors of earthquake in Pakistan using Davidson Trauma Scale. *J Affect Disord* 2012;136:238-43.
8. Beaudoin CE. News, social capital and health in the context of Katrina. *J Health Care Poor Underserved* 2007;18:418-30.
9. Wind TR, Komproe IH. The mechanisms that associate community social capital with post-disaster mental health: a multilevel model. *Soc Sci Med* 2012;75:1715-20.
10. Buttenheim A. Impact evaluation in the post-disaster setting: a case study of the 2005 Pakistan earthquake. *J Dev Effect* 2010;2:197-227.
11. Fergusson DM, Horwood LJ, Boden JM, et al. Impact of a major disaster on the mental health of a well-studied cohort. *JAMA Psychiatry* 2014;71:1025-31.
12. Arnberg FK, Gudmundsdottir R, Butwicka A, et al. Psychiatric disorders and suicide attempts in Swedish survivors of the 2004 southeast Asia tsunami: a 5 year matched cohort study. *Lancet Psychiatry* 2015;2:817-24.
13. Tsuboya T, Aida J, Hikichi H, et al. Predictors of depressive symptoms following the Great East Japan earthquake: A prospective study. *Soc Sci Med* 2016;161:47-54.
14. Blake H, Mo P, Malik S, et al. How effective are physical activity interventions for alleviating depressive symptoms in older people? A systematic review. *Clin Rehabil* 2009;23:873-87.
15. Bridle C, Spanjers K, Patel S, et al. Effect of exercise on depression severity in older people: systematic review and meta-analysis of randomised controlled trials. *Br J Psychiatry* 2012;201:180-5.
16. Schuch FB, Vancampfort D, Richards J, et al. Exercise as a treatment for depression: A meta-analysis adjusting for publication bias. *J Psychiatr Res* 2016;77:42-51.

17. Schuch FB, Vancampfort D, Rosenbaum S, et al. Exercise for depression in older adults: a meta-analysis of randomized controlled trials adjusting for publication bias. *Rev Bras Psiquiatr* 2016;38:247-54.

18. Yusuf HR, Croft JB, Giles WH, et al. Leisure-time physical activity among older adults. United States, 1990. *Arch Intern Med* 1996;156:1321-6.

19. Lucas M, Mekary R, Pan A, et al. Relation between clinical depression risk and physical activity and time spent watching television in older women: a 10-year prospective follow-up study. *Am J Epidemiol* 2011;174:1017-27.

20. Bernard P, Ninot G, Bernard PL, et al. Effects of a six-month walking intervention on depression in inactive post-menopausal women: a randomized controlled trial. *Aging Ment Health* 2015;19:485-92.

21. Kanamori S, Takamiya T, Inoue S. Group exercise for adults and elderly: Determinants of participation in group exercise and its associations with health outcome. *J Phys Fitness Sports Med* 2015;4:315-20.

22. Street G, James R, Cutt H. The relationship between organised physical recreation and mental health. *Health Promot J Austr* 2007;18:236-9.

23. Japan Health Promotion Fitness Foundation. Survey research on physical/psychological support activities through exercise and sports and their utilization method in affected areas of The Great East Japan Earthquake, 2012.

24. Tomata Y, Sato N, Kogure M, et al. Health effects of interventions to promote physical activity in survivors of the 2011 Great East Japan Earthquake. A longitudinal study. *Nihon Koshu Eisei Zasshi* 2015;62:66-72.

25. Ishigaki A, Higashi H, Sakamoto T, et al. The Great East-Japan Earthquake and devastating tsunami: an update and lessons from the past Great Earthquakes in Japan since 1923. *Tohoku J Exp Med* 2013;229:287-99.

26. Geospatial Information Authority of Japan. Area of wetted surface from Tsunami disaster, 2011.

27. Tani Y, Sasaki Y, Haseda M, et al. Eating alone and depression in older men and women by cohabitation status: The JAGES longitudinal survey. *Age Ageing* 2015;44:1019-26.

28. Koyama S, Aida J, Kawachi I, et al. Social support improves mental health among the victims relocated to temporary housing following the Great East Japan Earthquake and Tsunami. *Tohoku J Exp Med* 2014;234:241-7.

29. Hikichi H, Aida J, Tsuboya T, at al. Can community social cohesion prevent PTSD in the aftermath of disaster? A natural experiment from the 2011 Tohoku earthquake and tsunami. *Am J Epidemiol* 2016;183:902-10.

30. Wada T, Ishine M, Kita T, et al. Depression screening of elderly community-dwelling Japanese. *J Am Geriatr Soc* 2003;51:1328-9.

31. Burke WJ, Roccaforte WH, Wengel SP. The short form of the Geriatric Depression Scale: a comparison with the 30-item form. *J Geriatr Psychiatry Neurol* 1991;4:173-8.

32. Koyano W, Shibata H, Nakazato K, et al. Measurement of competence: reliability and validity of the TMIG Index of Competence. *Arch Gerontol Geriatr* 1991;13:103-16.

33. Rubin DB. *Multiple imputation for nonresponse in surveys*. Hoboken, NJ: Wiley-Interscience, 2004.

34. Carpenter JR, Kenward MG. *Multiple imputation and its application*. Hoboken, NJ: John Wiley & Sons, 2013.

35. Schreiner AS, Hayakawa H, Morimoto T, et al. Screening for late life depression: cut-off scores for the Geriatric Depression Scale and the Cornell Scale for Depression in Dementia among Japanese subjects. *Int J Geriatr Psychiatry* 2003;18:498-505.

36. Mammen G, Faulkner G. Physical activity and the prevention of depression: a systematic review of prospective studies. *Am J Prev Med* 2013;45:649-57.

37. Bolier L, Haverman M, Westerhof GJ, et al. Positive psychology interventions: a meta-analysis of randomized controlled studies. *BMC public health* 2013;13:119.

38. Proyer RT, Gander F, Wellenzohn S, et al. Positive psychology interventions in people aged 50-79 years: long-term effects of placebo-controlled online interventions on well-being and depression. *Aging Ment Health* 2014;18:997-1005.

39. Julien D, Gauvin L, Richard L, et al. The role of social participation and walking in depression among older adults: results from the VoisiNuAge study. *Can J Aging* 2013;32:1-12.

40. Gusi N, Reyes MC, Gonzalez-Guerrero JL, et al. Cost-utility of a walking programme for moderately depressed, obese, or overweight elderly women in primary care: a randomised controlled trial. *BMC public health* 2008;8:231.

41. Robertson R, Robertson A, Jepson R, et al. Walking for depression or depressive symptoms: A systematic review and meta-analysis. *Ment Health Phys Act* 2012;5:66-75.

42. Ekkekakis P, Parfitt G, Petruzzello SJ. The pleasure and displeasure people feel when they exercise at different intensities: decennial update and progress towards a tripartite rationale for exercise intensity prescription. *Sports Med* 2011;41:641-71.

Figure legends:

Figure 1. Participants flow in the Iwanuma Project and in the present study for with and without multiple imputation analysis.

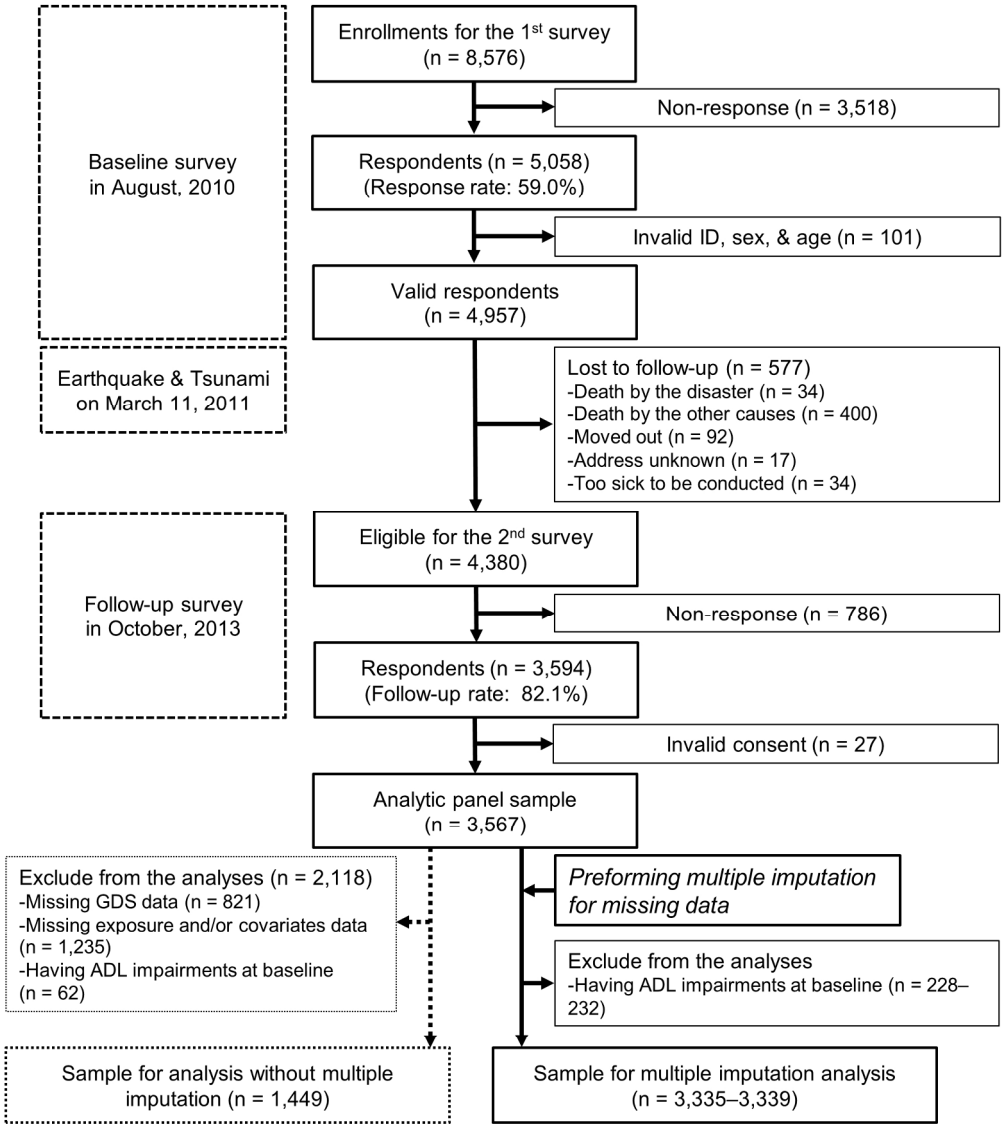

Figure 1. Participants flow in the Iwanuma Project and in the present study for with and without multiple imputation analysis

194x225mm (300 x 300 DPI)

Supplementary Table 1. Relationship of exposure and covariate variables with change in Geriatric Depression Scale score (complete cases: n = 1,449)

	n	*r*	*P* (Pearson's correlation)
Change in group exercise participation	1,449	-0.060	0.024
Change in walking habit	1,449	-0.053	0.083
Age	1,449	0.075	0.004
Educational attainment	1,449	0.039	0.143
Change in equivalent income	1,449	-0.005	0.857
Change in IADL score	1,449	-0.199	<0.001
	n	Mean	SD	*P* (One-way ANOVA)
Sex				
Male	827	0.1	2.6	0.255
Female	622	0.0	2.6	
Psychological disorder				
No	1,441	0.1	2.6	0.304
Yes	8	-0.9	1.9	
Disease status (other than psychological disorder)				
No disease	371	0.2	2.5	0.418
One or more disease(s)	1,078	0.0	2.6	
Activities of daily living				
Maintain ADL	1,394	0.0	2.5	<0.001
Impaired ADL after the	55	2.0	3.7	
Change in drinking habit				
Drink.→Drink.	580	0.1	2.2	0.055
Non→Drink.	33	-0.6	2.9	
Drink.→Non	122	0.5	3.0	
Non→Non	714	0.0	2.7	
Change in smoking habit				
Non→Non	1,261	0.0	2.6	0.001
Smok.→Non	55	1.4	2.8	
Non→Smok.	7	0.9	3.6	
Smok.→Smok.	126	-0.2	2.4	
Change in job status				
Working→Working	196	-0.3	2.2	0.276
No→Working	40	0.1	3.1	
Working→No	118	0.2	2.6	
No→No	1,095	0.1	2.6	
Dwelling house damage				
No damage	627	-0.1	2.5	0.004
Some damage	640	0.1	2.6	
Partial destruction	93	0.2	3.0	
Almost destruction	42	0.3	2.6	
Complete destruction	47	1.4	2.8	
Lost family member(s)				
No	1,079	0.1	2.6	0.838
Yes	370	0.1	2.6	

SD: standard deviation, ANOVA: analysis of variance, ADL: activities of daily living, IADL: instrumental activities of daily living.

Supplementary Table 2. Multiple linear regression of changes in group exercise participation and walking habit (converted into Z-scores) with change in depressive symptoms by analyzing complete data set (n = 1,449)

	Crude model						Model 1						Model 2						Model 3					
	B	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*
Change in group exercise participation	-0.139	-0.276	-0.002	-0.056	-1.99	0.047	-0.125	-0.261	0.010	-0.051	-1.82	0.069	-0.112	-0.241	0.017	-0.045	-1.71	0.088	-0.052	-0.187	0.083	-0.021	-0.75	0.453
Change in walking habit *(30.7 mins/day)*	-0.108	-0.251	0.035	-0.041	-1.48	0.138	-0.098	-0.241	0.044	-0.037	-1.35	0.176	-0.038	-0.180	0.105	-0.014	-0.52	0.602	-0.029	-0.173	0.115	-0.011	-0.39	0.695
Age *(year)*							0.033	0.008	0.057	0.070	2.59	0.010	0.011	-0.017	0.039	0.023	0.75	0.455	0.009	-0.019	0.037	0.020	0.66	0.507
Sex *(1 men, 2 women)*							-0.127	-0.394	0.141	-0.024	-0.93	0.353	0.006	-0.326	0.338	0.001	0.03	0.973	0.004	-0.327	0.336	0.001	0.03	0.979
Psychological disorder *(0 no, 1 yes)*													-1.131	-2.666	0.403	-0.033	-1.45	0.148	-1.088	-2.588	0.411	-0.031	-1.42	0.155
Disease status *(0 no, 1 one or more)**													-0.201	-0.502	0.099	-0.034	-1.31	0.189	-0.208	-0.510	0.093	-0.035	-1.35	0.176
Educational attainment *(year)*													0.076	0.010	0.142	0.064	2.26	0.024	0.081	0.014	0.147	0.068	2.38	0.018
Impaired ADL *(0 no, 1 impaired)*													1.115	0.153	2.076	0.083	2.27	0.023	1.124	0.174	2.073	0.083	2.32	0.020
Changes in drinking habits																								
Non→Drink.													-0.638	-1.580	0.303	-0.037	-1.33	0.184	-0.620	-1.556	0.315	-0.036	-1.30	0.193
Drink.→Non													0.195	-0.357	0.746	0.021	0.69	0.488	0.180	-0.372	0.731	0.019	0.64	0.522
Non→Non													-0.266	-0.592	0.059	-0.052	-1.60	0.109	-0.268	-0.594	0.058	-0.052	-1.61	0.107
Changes in smoking habits																								
Smoke.→Non													1.127	0.435	1.819	0.084	3.19	0.001	1.117	0.431	1.803	0.083	3.19	0.001
Non→Smoke.													0.853	-1.665	3.371	0.023	0.66	0.506	0.821	-1.687	3.328	0.022	0.64	0.521
Smoke.→Smoke.													-0.234	-0.690	0.222	-0.026	-1.01	0.315	-0.226	-0.676	0.225	-0.025	-0.98	0.326
Changes in job status																								
No→Working													0.484	-0.502	1.470	0.031	0.96	0.336	0.450	-0.536	1.436	0.029	0.90	0.371
Working→No													0.260	-0.291	0.810	0.028	0.93	0.355	0.259	-0.290	0.808	0.027	0.93	0.354
No→No													0.292	-0.065	0.648	0.049	1.60	0.109	0.289	-0.069	0.646	0.048	1.59	0.113
Dwelling house damage *(1 no damage → 5 complete*													0.255	0.096	0.413	0.092	3.15	0.002	0.258	0.098	0.418	0.093	3.16	0.002
Death of family member(s) *(0 no, 1 yes)*													0.085	-0.223	0.394	0.014	0.54	0.588	0.097	-0.212	0.405	0.016	0.61	0.539
Change in equivalent income *(million yen)*													-0.025	-0.133	0.082	-0.012	-0.47	0.642	-0.017	-0.125	0.091	-0.008	-0.31	0.759
Change in IADL *(score)*													-0.243	-0.356	-0.131	-0.156	-4.25	<0.001	-0.244	-0.356	-0.132	-0.156	-4.26	<0.001
Interaction																								
Change in exercise x house damage																			0.200	0.017	0.383	0.061	2.14	0.032
Change in walking time x house damage																			0.091	-0.044	0.226	0.037	1.32	0.189

* other than psychological disorder.

CI: confidence interval, ADL: activities of daily living, IADL: instrumental activities of daily living.

Supplementary Table 3. Multiple linear regression of changes in group exercise participation and walking habit (converted into Z-scores) with change in depressive symptoms by analyzing multiply imputed data sets in older adults with or without depression (GDS >= 5 or < 5, respectively)

	Baseline GDS < 5 (n = 2,299-2,309)						Baseline GDS >= 5 (n = 1,029-1,039)					
	B	95% CI		*β*	*t*	*P*	*B*	95% CI		*β*	*t*	*P*
Crude model												
Change in group exercise participation	-0.174	-0.260	-0.088	-0.057	-3.97	<0.001	-0.263	-0.600	0.073	-0.086	-1.54	0.125
Change in walking habit	-0.146	-0.250	-0.041	-0.050	-2.73	0.006	-0.260	-0.470	-0.049	-0.089	-2.42	0.016
Model 1												
Change in group exercise participation	-0.155	-0.240	-0.071	-0.051	-3.61	<0.001	-0.237	-0.569	0.096	-0.077	-1.40	0.163
Change in walking habit	-0.139	-0.243	-0.035	-0.048	-2.62	0.009	-0.236	-0.445	-0.027	-0.081	-2.22	0.027
Model 2												
Change in group exercise participation	-0.147	-0.229	-0.066	-0.048	-3.54	<0.001	-0.195	-0.532	0.141	-0.064	-1.14	0.255
Change in walking habit	-0.048	-0.147	0.051	-0.016	-0.94	0.345	-0.119	-0.325	0.087	-0.041	-1.13	0.257
Model 3												
Change in group exercise participation	-0.135	-0.218	-0.051	-0.046	-3.37	0.001	-0.226	-0.560	0.107	-0.080	-1.39	0.164
Change in walking habit	-0.037	-0.137	0.063	-0.015	-0.89	0.372	-0.124	-0.328	0.079	-0.051	-1.42	0.155
Change in group exercise participation x house damage	0.046	-0.044	0.135	0.015	1.00	0.318	0.141	-0.174	0.456	0.047	0.88	0.380
Change in walking habit x house damage	0.063	-0.030	0.156	0.022	1.32	0.187	0.179	-0.035	0.394	0.062	1.64	0.101

Z-scores of 1.0 mean 44.5 days/year in the change in frequency of group exercise participation and 30.7 mins/day in the change in daily walking time.

Model 1: crude model + age and sex

Model 2: model 1 + psychological disorder, disease status, educational attainment, impaired activities of daily living, dwelling house damage, death of family members, changes in drinking habits, smoking habits, job status, equivalent income, and instrumental activities of daily living score.

Model 3: model 2 + interaction terms

GDS: Geriatric Depression Scale, CI: confidence interval.

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	■(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		■(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	■ (P4L1-) Explain the scientific background and rationale for the investigation being reported
Objectives	3	■ (P5L7-) State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	■ (P5L15-) Present key elements of study design early in the paper
Setting	5	■ (P5L15-) Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	■ (P5L15-) (*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(N/A) (*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	■ (P6L11-) Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	■ (P5L15- & P6L11-) For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	■ (P7L10-) Describe any efforts to address potential sources of bias
Study size	10	(N/A) Explain how the study size was arrived at
Quantitative variables	11	■ (P7L10-) Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	■ (P7L10-) (*a*) Describe all statistical methods, including those used to control for confounding
		(N/A) (*b*) Describe any methods used to examine subgroups and interactions
		■ (P7L10-) (*c*) Explain how missing data were addressed
		■ (Figure 1) (*d*) If applicable, explain how loss to follow-up was addressed
		(N/A) (*e*) Describe any sensitivity analyses
Results		
Participants	13*	■ (Figure 1) (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		■ (Figure 1) (b) Give reasons for non-participation at each stage
		■ (Figure 1) (c) Consider use of a flow diagram
Descriptive data	14*	■ (Table 1 & P8L7-) (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		■ (Table 1) (b) Indicate number of participants with missing data for each variable of interest
		■ (P5L26-) (c) Summarise follow-up time (eg, average and total amount)
Outcome data	15*	■ (Table 1) Report numbers of outcome events or summary measures over time
Main results	16	■ (Table 3) (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which

		confounders were adjusted for and why they were included
		(N/A) (*b*) Report category boundaries when continuous variables were categorized
		(N/A) (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	(N/A) Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	■ (P17L3-) Summarise key results with reference to study objectives
Limitations	19	■ (P19L8-) Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	■ (P17L13-) Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	■ (P19L17-) Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	■ (P20L16-) Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.