HHS Public Access

Author manuscript

Soc Sci Med. Author manuscript; available in PMC 2020 November 01.

Published in final edited form as:

Soc Sci Med. 2020 November ; 264: 113385. doi:10.1016/j.socscimed.2020.113385.

Causal effect of deteriorating socioeconomic circumstances on new-onset arthritis and the moderating role of access to medical care: A natural experiment from the 2011 great east Japan earthquake and tsunami

Takaaki Ikeda[a,b,*], **Jun Aida**[c,d], **Ichiro Kawachi**[e], **Katsunori Kondo**[f,g], **Ken Osaka**[b]

[a]Department of Health Policy Science, Graduate School of Medical Science, Yamagata University, Yamagata, Japan

[b]Department of International and Community Oral Health, Tohoku University Graduate School of Dentistry, Miyagi, Japan

[c]Department of Oral Health Promotion, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

[d]Division for Regional Community Development, Liaison Center for Innovative Dentistry, Graduate School of Dentistry, Tohoku University, Miyagi, Japan

[e]Department of Social and Behavioral Sciences, Harvard School of Public Health, Boston, MA, USA

[f]Department of Social Preventive Medical Sciences, Center for Preventive Medical Sciences, Chiba University, Chiba, Japan

[g]Department of Gerontological Evaluation, Center for Gerontology and Social Science, National Center for Gedatrics and Gerontology, Aichi, Japan

Abstract

Socioeconomic disadvantage is a risk factor for arthritis, but its causal relationship remains unclear. This study examined the causal relationship between socioeconomic circumstances and new-onset arthritis by taking advantage of the “natural experiment” that resulted from the Great East Japan Earthquake and Tsunami. The baseline survey was conducted in August 2010, 7 months before the disaster. Self-reported questionnaires were mailed to all eligible residents of Iwanuma City in Miyagi Prefecture. The earthquake and tsunami occurred on March 11, 2011. The follow-up survey was conducted in October 2013, as well as the gathering of information about disaster damage (housing damage and subjective deterioration of economic circumstances)

*Corresponding author. Department of Health Policy Science, Graduate School of Medical Science, Yamagata University, Yamagata, Japan, 2-2-2 Iidanishi, Yamagata, Yamagata, 990-9585, Japan. t.ikeda0110@gmail.com (T. Ikeda).

Credit author statement

T.I. created the analysis plan, analyzed the data, and drafted the manuscript. J.A., I.K., K.K., and K.O. supervised data collection for the whole study. J. A. helped the analyses. I.K. conceived the study design and participated in the interpretation of data and manuscript preparation. All of the authors discussed the data and results and critically revised the manuscript.

Declaration of competing interest

None.

and health-related information. We used a two-stage least squares instrumental variable model to analyze 2360 survivors who did not have arthrosis at baseline, of whom 95 (4.0%) developed arthritis over the 2.5-year follow-up period. We used the linear probability model for the estimations. Our results revealed that both the subjective deterioration of economic circumstances and housing damage were associated with the development of arthritis (95% confidence interval [CI], 0.08 [0.03–0.12] and 0.02 [0.01–0.04], respectively). In addition, we also found that the disruption of access to orthopedics was associated with the development of arthritis. Our findings added robust evidence of the causal relationship between worsening economic circumstances and the development of arthritis. Our study emphasized the importance of recovery as well as the establishment of the post-disaster orthopedic medical system in the aftermath of a disaster.

Keywords

Arthrosis; Instrumental variable models; IV; Natural disaster; Natural experiment; Orthopedics; Osteoarthritis; Socioeconomic status

1. Introduction

Arthritis is a degenerative disease that causes pain and inflammation in the joints; it is also known as one of the leading causes of disability (Theis et al., 2018). In the USA, 54.4 million adults, approximately one-quarter of all adults, are affected by this disease (Barbour et al., 2017). With the increase in the age of the population, the prevalence of arthritis is expected to increase significantly by 2040, with as many as 78 million US adults expected to be diagnosed with arthritis.

Several previous studies have reported that socioeconomic status (SES) is associated with arthritis, and that people with a lower SES tended to suffer more from this disease (Bengtsson et al., 2005; Cleveland et al., 2013; Leigh and Fries, 1991). In general, individuals with lower SES are more likely to engage in heavy labor, which is considered as one of the primary risk factors for arthritis (Mehlum et al., 2008; O'Reilly et al., 2000). In addition, these individuals are more likely to suffer from previous injuries, which also increases the risk for subsequent arthritis (Felson, 1994). Moreover, obesity, which is associated with SES (McLaren, 2007; Shiba et al., 2019; Wardle et al., 2002), has also been reported as a common risk factor for arthritis (Chaganti and Lane, 2011; Daïen and Sellam, 2015).

However, there are limited studies on the causal relationship between SES and the new-onset arthritis because of the inherent nature of observational studies (Bengtsson et al., 2005; Cleveland et al., 2013; Leigh and Fries, 1991). To overcome this limitation, the instrumental variable (IV) model enabled us to mimic randomized control trials in observational studies (Greenland, 2000). This model can provide a robust causal relationship by applying an IV, which is only associated with the exposure and only affects the outcome *via* the exposure (Davies et al., 2013).

Thus far, earlier works have examined the association between health status and natural disasters, such as earthquake, Tsunami, and hurricane (Aida et al., 2017; Fergusson et al., 2014; Hikichi et al., 2016; Matsuyama et al., 2017; Tsuboya et al., 2016; Wilson-Genderson et al., 2018). These studies took advantage of these so-called natural experiments (Craig et al., 2012), in which data on health conditions both *before* and after the disasters were available (Aida et al., 2017; Fergusson et al., 2014; Hikichi et al., 2016; Matsuyama et al., 2017; Tsuboya et al., 2016; Wilson-Genderson et al., 2018). Among them, two studies have attempted to elucidate causal relationships between disaster damage and various health conditions in the survivors of the Great East Japan Earthquake and Tsunami by using IV models (IV as the distance from the coastlines) (Hikichi et al., 2016; Matsuyama et al., 2017). Following these studies, we sought to investigate the causal relationship between socioeconomic circumstances and the development of arthritis in the survivors of the Great East Japan Earthquake and Tsunami using the IV model.

2. Methods

2.1. Data

We used repeatedly measured health and SES from the Iwanuma Study, a part of the Japan Gerontological Evaluation Study (JAGES), which is a large-scale prospective cohort study that aimed to evaluate the health of older adults in Japan (Kondo, 2016; Kondo et al., 2018). We used data from one of the research field sites of the JAGES: Iwanuma City, on the northeastern coast of Japan. The baseline survey was conducted in August 2010, 7 months *before* the disaster, and self-reported questionnaires were mailed to all eligible residents of the city. On March 11, 2011, Iwanuma was approximately 80 km west of the earthquake epicenter, and the disaster killed 186 people and destroyed 5428 houses (Miyagi Prefectural Government, 2019). The follow-up survey was conducted in October 2013 (31 months after the disaster), and the investigators visited the survivors' homes in order to collect information about the disaster damage, as well as health-related information. We included participants who responded to both the baseline and follow-up surveys and who did not have arthrosis at baseline. We excluded participants who lacked information on arthrosis at baseline. Consequently, 2360 participants were included in our final analysis (Fig. 1).

2.2. Dependent variable: new-onset arthritis

Information on the new-onset arthritis was collected by using self-reported questionnaire in the 2013 follow-up survey, which included the following question intended for the participants: "Circle all the illnesses or injuries you acquired after the earthquake." We identified participants with incident arthritis if they chose "Arthritis" out of the 24 items listed.

2.3. Exposures: disaster damage

We used two types of disaster damage: subjective deterioration of economic circumstances and housing damage. Subjective deterioration of economic circumstances was assessed by asking, "Was your economic situation affected by the disaster?," with possible answers of "became worse," "became partially worse," "no change," "partially improved," or "improved." Those who responded "no change," "partially improved," and "improved" were grouped together in accordance with a previous study (Matsuyama et al., 2017). Housing damage was determined by local government inspectors (an objective indicator used for the survivors' compensation). Housing damage was evaluated by asking, "What was the formal classification of the damage to your house?" with possible answers of "completely destroyed," "mostly destroyed," "half-destroyed," "partially destroyed," or "no damage."

2.4. Covariates and potential mediators

We used several covariates as follows: age (65–69, 70–74, 75–79, 80–84, or ≥85 years); sex; SES (educational attainment and equivalized household income); body mass index (BMI) (<18.5 kg/m^2, 18.5–24.9 kg/m^2, 25.0–29.9 kg/m^2, and ≥30 kg/m^2); any self-reported comorbidities for osteoporosis, traumatic injuries, or fractures; smoking status (never, former, or current); and depressive symptoms assessed by the Japanese short version of the Geriatric Depression Scale (≤4, 5–9, ≥10) (Wada T, Ishine M, Kita T, Fujisawa M, 2003). All of the previously mentioned covariates were assessed at baseline, i.e., before the disaster.

We also considered the following follow-up variables as potential mediators: loss of loved ones as a result of the disaster, psychological distress, and disruption of access to orthopedics at follow-up. The change in BMI between the baseline and follow-up was also considered as a potential mediator.

Psychological distress was assessed using the truncated version of the Kessler Psychological Distress Scale, and the participants were grouped into the following three groups: none, <5; moderate, 5–12; and severe, ≥13 (Kessler et al., 2002). Disruption of access to orthopedics due to the disaster was assessed by asking, "Did you experience any disruption of access to health care? Circle all that apply." We identified disrupted participants if they chose "Orthopedics" out of the six possible answers.

2.5. Statistical analyses

We performed a descriptive analysis of the participants' characteristics, exposures, and outcome. Then, two types of regression analysis were performed. The exposure variables were added separately to the regression models to avoid over-adjustment bias (Schisterman et al., 2009). We first performed the "conventional" ordinary least squares (OLS) regression with robust standard errors, which is represented as follows:

$$Y_i = \alpha_0 + \alpha_1 Disaster\ Damage_i + \theta Covariates_i + \varepsilon_i$$

,where Y denotes the outcome of the interest; *Disaster Damage*, the exposures (subjective deterioration of economic circumstances or housing damage); *Covariates*, the set of covariates; and ε, the error term.

We then applied the two-stage least squares IV model with robust standard errors. We used distance from the coastline as an IV, in line with previous studies (Hikichi et al., 2016; Matsuyama et al., 2017). IVs must meet the following three conditions: 1) associated with exposure assignment (relevance); 2) not directly associated with the outcome and only associated with the outcome through exposure (exclusion restriction); and 3) independent of any of the covariates (Davies et al., 2013). The distance from the coastline to each resident's address at baseline was assessed using the geographic information systems and was used as an IV for the disaster damage. Thus, our IV model can be written as follows:

$$Disaster\ Damage_i = \gamma_0 + \gamma_1 Distance_i + \delta Covariates_i + \tau_i$$

$$Y_i = \beta_0 + \beta_1 \widehat{Disaster\ Damage_i} + \phi Covariates_i + \varepsilon_i$$

The first equation is the first stage of our regression model in which we predicted disaster damage (exposures) using our IV (distance from the coastline) and the set of covariates. The second equation represents the second stage of our regression model. In the second stage, we regressed our outcome of the interest (new-onset arthritis) on the predicted value of $\widehat{Disaster\ Damage_i}$ from the first stage regression and the set of covariates. We applied linear probability models in both the first- and second stage equations on the basis of the recommendation of previous studies (Angrist and Pischke, 2008; Matsuyama et al., 2019). The strength of the instruments was assessed using an *F*-test of the joint contribution of the two instruments in predicting treatment, whereby *F*-statistics > 10 indicate that instruments are sufficiently strong (Angrist and Pischke, 2008). For sensitivity analysis, we conducted the same analysis in which we added the potential mediators and checked the reduction in coefficients by the mediators. All the missing variables in the covariates were turned into dummy variables and added into the models. All analyses were conducted using Stata, version 16.0 (StataCorp LLC, College Station, Texas).

3. Results

Table 1 presents the characteristics and health status of the study participants. Among the eligible participants (n = 2360), 95 developed arthritis after the disaster (4.0%). The participants who had economic difficulty or housing damage were more likely to develop arthritis.

Tables 2 and 3 present the results of our OLS and IV models. The *F*-statistic was 197.7 for the analysis of the subjective deterioration of economic circumstances and 733.0 for the analysis of housing damage; these values suggest a sufficient correlation between IV regression and the exposure variable. Subjective deterioration of economic circumstances was significantly associated with new-onset arthritis in both the OLS and the IV models of the coefficient (95% confidence interval [CI], 0.02 [0.001–0.03] in the OLS model and 0.08 [0.03–0.12] in the IV model) (Table 2). The result of our IV model indicates that people who reported “became worse” for their subjective economic circumstances had a 16% increase in the probability of developing arthritis compared with those who reported “no change/ improved.”

Similarly, housing damage was significantly associated with the development of arthritis in both the OLS and IV models (95% CI, 0.01 (0.002–0.02) in the OLS model and 0.02 (0.01–0.04) in the IV model) (Table 3). The result of our IV model indicates that people who experienced total home destruction had an 8% increase in the probability of developing arthritis compared with those who did not experience home destruction.

For the sensitivity analyses, the loss of loved ones in the disaster, psychological distress after the disaster, and change in BMI between baseline and follow-up were not significantly associated with new-onset arthritis (Tables 4 and 5). However, disruption of access to orthopedics after the disaster was associated with new-onset arthritis in both the OLS and IV models. The association between disaster damage and the development of arthritis was somewhat attenuated but remained significant in our IV model (Tables 4 and 5).

4. Discussion

To the best of our knowledge, this study is the first to examine the causal relationship between disaster damage and the new-onset arthritis. Our results revealed significant associations between subjective deterioration of economic circumstances and housing damage and the development of arthritis.

Several previous observational studies have reported that lower SES (educational attainment or income level) is associated with the new-onset arthritis (Bengtsson et al., 2005; Cleveland et al., 2013; Leigh and Fries, 1991), which is in line with the results of the current study. However, these studies were observational studies, and there is room for causal inference. However, we succesfully added robust evidence that worsened the economic circumstances that occurred as a result of disaster damage and caused arthritis by applying the IV model, where it was possible to adjust unmeasured confounders. In addition, previous studies have reported the causal relationship between disaster damage and health outcomes, such as dementia (Hikichi et al., 2016) and oral health (Matsuyama et al., 2017), using the IV model, the results of which were consistent with those of the current study. Moreover, lower SES occupations was also reported to be a risk for arthritis (Cleveland et al., 2013; Leigh and Fries, 1991), that is, those individuals with lower SES occupations are more likely to suffer from previous injuries, possibly leading to subsequent arthritis (Felson, 1994). However, since the risk of injury/heavy physical workload is temporally downstream of working in lower SES occupations (e.g. manual labor), these factors are not considered to be confounders of the association between economic circumstances and risk of new-onset arthritis. In addition, most of our participants were retired at the time of the baseline survey, and were therefore unlikely to change their jobs during follow-up.

The possible mechanisms underlying the association between worsening economic circumstances and the development of arthritis are as follows: 1) changes in health-related behaviors (e.g., healthcare utilization and/or overweight/obesity) and 2) psychosocial distress. Indeed, we found that the disruption of access to orthopedics was associated with the new-onset arthritis and somewhat attenuated the association between worsened economic circumstances and the development of arthritis. This result suggests that the disruption of access to orthopedics acts a mediator between economic circumstances and arthritis. An observational study from the Netherlands reported that lower educational level was associated with allied healthcare usage among patients with rheumatoid arthritis, but not with other healthcare services, such as access to rheumatologists or to general practitioners

(Jacobi et al., 2003). The difference between studies may be explained by the difference in the study design, in that our study was a so-called natural experiment that was conducted by chance due to the emergency situation of the earthquake, whereas the previous study was conducted in normal times that were unaffected by disaster (Jacobi et al., 2003). In normal situations, access to health care is supposed to be correlated with SES; however, following a major disaster, access to health care is disrupted by disaster rather than socioeconomic conditions. Furthermore, a natural experiment observational study from Japan also reported that the disruption of access to psychiatry was associated with poor mental health in the aftermath of the disaster (Tsuboya et al., 2016), which is in agreement with the results of the current study.

Surprisingly, body mass index at baseline was not significantly associated with the development of arthritis. In addition, changes in BMI between baseline and follow-up were also not associated with the new-onset arthritis. A previous longitudinal study from Japan reported that housing damage after the earthquake and tsunami was associated with obesity (Shiba et al., 2019). Thus, our results were inconsistent with the previous studies that indicated that obesity is a risk factor for arthritis (Chaganti and Lane, 2011; Daïen and Sellam, 2015). This discrepancy may be explained by the fact that participants with deteriorating economic circumstances due to the disaster were more likely to suffer from an injury on the day of the disaster because of the disruption of access to orthopedics. Post-traumatic arthritis is considered to be a condition triggered by an acute joint injury that possibly causes choronic arthritis (Punzi et al., 2016). Moreover, it is also considered that treatment for inflammation occurring immediately after joint injury plays an important role in preventing the development chronic arthritis (Punzi et al., 2016). Therefore, it is possible that participants with deteriorating economic circumstances caused by the disaster were more likely to refrain from visiting orthopedics for an injury on the day of the disaster; this may lead to an accelerated development of arthritis in the affected limbs rather than the body mass index itself. In that sense, we believe that it is important to establish a medical system immediately after the disaster for those with joint injuries to prevent future new-onset arthritis. Unfortunately, we could not obtain the actual information about the injury on the day of the disaster. Hence, future studies with more detailed information on somatic diseases are expected to investigate this possibility.

Besides, loss of loved ones in the disaster and psychological distress were not significantly associated with the development of arthritis in the current study. These results were partially consistent with the previous studies conducted after the earthquake, which demonstrated that loss of loved ones in the disaster was not associated with depressive symptoms (Tsuboya et al., 2016), incident dementia (Hikichi et al., 2016), or tooth loss (Matsuyama et al., 2017). However, psychological distress was associated with the new-onset arthritis (measured by the self-reported questionnaire) in the UK general population (McLachlan and Gale, 2018). Moreover, two observational studies also reported that depression or anxiety increased the risk of incident arthritis (Patten et al., 2008; Scott et al., 2011). These results were inconsistent with those of the current study. This discrepancy might be explained by the results obtained from “conventional” regression models in previous studies (McLachlan and Gale, 2018; Patten et al., 2008; Scott et al., 2011), which were likely to be biased by unmeasured confounders or reverse causation. Psychological distress is considered to affect immune function and to increase the level of inflammation (Segerstrom and Miller, 2004; Wium-Andersen et al., 2013), whereas arthritis, in general, is associated with a higher level of inflammation (Jin et al., 2015). Moreover, the higher level of inflammation was associated with pain (Jin et al., 2015); thus, it is possible that pain was caused by inflammation due to arthritis, which was considered to be the primary cause of the reported psychological distress. However, future studies are expected to examine the possible mechanism for the relationship between psychological distress and arthritis as we did not assess the immune markers. By integrating these findings, the present study suggests that ensuring access to orthopedic care is the most important in preventing the new-onset arthritis.

When we consider the coefficient for the association between subjective deterioration in economic circumstances and the new-onset arthritis, we believe that the coefficient of 0.08 in our IV model is crucial due to the following reasons: the probability of the development of arthritis was 16% higher in participants who reported “became worse” for their subjective economic circumstances, and this magnitude is sufficiently large among the variables included in our regression model. In addition, we also found housing to be important. Indeed, the coefficient of 0.02 was comparable to the magnitude of associations between the other variables and the new-onset arthritis because the probability of developing arthritis was 8% higher in participants who experienced total home destruction, which is the highest among the variables included in the current model.

The current study has several strengths and limitations that should be noted. First, with regard to the strengths, we had general and health data of survivors prior to the disaster. Second, the nature of the “natural experiment” enabled us to mimic a RCT and infer a causal relationship between economic circumstances and the new-onset arthritis. Our study also had several limitations that warrant consideration. First, we used the self-reported questionnaire to detect the new-onset arthritis, and did not use doctor-diagnosed arthritis development, which may have resulted in potential misclassification. In addition, we could not identify the detailed type of the disorder (i.e., osteoarthritis or rheumatoid arthritis). However, we believe that the accuracy of our outcome is acceptable, given that a systematic review of the validity of self-reported arthritis (compared to clinical diagnosis) found that the pooled sensitivity and specificity was 0.71 and 0.79, respectively (Peeters et al., 2015). Thus, misclassification of the outcome is likely to have been non-differential (the sensitivity/specificity of self-report suggests that people are as likely to misreport *not* having arthritis as falsely reporting that they have the disease). This type of misclassification is unlikely to induce bias in the association between exposure and outcome (Rothman et al., 2008). Second, there is a possibility that the question regarding the disruption of access to orthopedics may have resulted in an underestimation; i.e., it is possible that some participants with no complaints did not circle the answer even though their access was actually disrupted. However, we believe that we were able to collect, with some degree of accuracy, the accessibility of orthopedics services for participants who needed treatment for joint injuries sustained as a result of the disaster. Third, we could not identify other mediating factors because of limited information on this topic. Hence, future studies are expected to identify other effective prevention strategies for arthritis. Fourth, the generalizability of the present results to other natural disasters, such as hurricanes, is unclear. For example, while hurricanes are somewhat predictable, earthquakes are not, and the damage from the disaster itself and its impact on health may be different (Wilson-Genderson et al., 2018). Moreover, it is also unclear whether participants in the present study are representative of all survivors of the Great East Japan Earthquake and Tsunami. We analyzed participants in only one municipality, whereas the influence of the disaster was wide-ranging. For example, some people suffered from the nuclear power plant accident.

5. Conclusions

We revealed that worsening economic circumstances were causally related to the new-onset arthritis among survivors of the 2011 Great East Japan Earthquake and Tsunami. We also showed that the disruption of access to orthopedics was associated with the development of arthritis. Hence, our study emphasized the importance of recovery and the establishment of the post-disaster orthopedic medical system in the aftermath of a disaster.

Acknowledgments

Funding

This study used data from the Japan Gerontological Evaluation Study (JAGES). This study was supported by a grant from the National Institutes of Health grants (R01 AG042463 and 2R01 AG042463-06); several Health and Labour Science Research Grants (Comprehensive Research on Aging and Health) from the Japanese Ministry of Health, Labour, and Welfare (grants: H22-Choju-Shitei-008, H24-Choju-Wakate-009, H25-Choju-Ippan-003, H28-Choju-Ippan-002, and H29-Chikyukibo-Ippan-001); Grants-in-Aid for Scientific Research from the Japanese Society for the Promotion of Science (grants: KAKENHI 23243070, 22390400, 24390469, 19K19818, 19H03860, and 20H00557); a grant from the Strategic Research Foundation Grant-Aided Project for Private Universities from the Japanese Ministry of Education, Culture, Sports, Science, and Technology (grant: S0991035); Open Innovation Platform with Enterprises, Research Institute and Academia (grants: OPERA and JPMJOP1831) from Japan Science and Technology (JST); the Research Funding for Longevity Sciences from National Center for Geriatrics and Gerontology (grant: 20–19); and Research and Development Grants for Longevity Science from the Japan Agency for Medical Research and Development (grants: JP19dk0110034, JP20dk0110034). The funders played no role in the study design, data collection and analysis, or the decision to publish this report.

References

Aida J, Hikichi H, Matsuyama Y, Sato Y, Tsuboya T, Tabuchi T, Koyama S, Subramanian SV, Kondo K, Osaka K, Kawachi I, 2017 Risk of mortality during and after the 2011 Great East Japan Earthquake and Tsunami among older coastal residents. Sci. Rep 7, 16591 10.1038/s41598-017-16636-3. [PubMed: 29185489]

Angrist JD, Pischke J-S, 2008 Mostly Harmless Econometrics: an Empiricist's Companion. Princeton University Press, Princeton.

Barbour KE, Helmick CG, Boring M, Brady TJ, 2017 Vital Signs: prevalence of doctor-diagnosed arthritis and arthritis-attributable activity limitation-United States, 2013-2015. Morb. Mortal. Wkly. Rep 66, 246–253. 10.15585/mmwr.mm6609e1.

Bengtsson C, Nordmark B, Klareskog L, Lundberg I, Alfredsson L, 2005 Socioeconomic status and the risk of developing rheumatoid arthritis: results from the Swedish EIRA study. Ann. Rheum. Dis 64, 1588–1594.10.1136/ard.2004.031666. [PubMed: 15843455]

Chaganti RK, Lane NE, 2011 Risk factors for incident osteoarthritis of the hip and knee. Curr. Rev. Musculoskelet. Med 10.1007/s12178-011-9088-5.

Cleveland RJ, Schwartz TA, Prizer LP, Randolph R, Schoster B, Renner JB, Jordan JM, Callahan LF, 2013 Associations of educational attainment, occupation, and community poverty with Hip osteoarthritis. Arthritis Care Res. 65, 954–961. 10.1002/acr.21920.

Craig P, Cooper C, Gunnell D, Haw S, Lawson K, Macintyre S, Ogilvie D, Petticrew M, Reeves B, Sutton M, Thompson S, 2012 Using natural experiments to evaluate population health interventions:

new medical research council guidance. J. Epidemiol. Community Health 66, 1182–1186. 10.1136/jech-2011-200375. [PubMed: 22577181]

Daïen CI, Sellam J, 2015 Obesity and inflammatory arthritis: impact on occurrence, disease characteristics and therapeutic response. RMD Open 29, e000012 10.1136/rmdopen-2014-000012..

Davies NM, Smith GD, Windmeijer F, Martin RM, 2013 Issues in the reporting and conduct of instrumental variable studies: a systematic review. Epidemiology 24, 363–369. 10.1097/EDE.0b013e31828abafb. [PubMed: 23532055]

Felson DT, 1994 Do occupation-related physical factors contribute to arthritis? Bailliere's Clin. Rheumatol 8, 63–77. 10.1016/S0950-3579(05)80225-0. [PubMed: 8149450]

Fergusson DM, Horwood LJ, Boden JM, Mulder RT, 2014 Impact of a major disaster on the mental health of a well-studied cohort. JAMA Psychiatry 71, 1025–1031. 10.1001/jamapsychiatry.2014.652. [PubMed: 25028897]

Greenland S, 2000 An introduction to instrumental variables for epidemiologists. Int. J. Epidemiol 29, 722–729. 10.1093/ije/29.4.722. [PubMed: 10922351]

Hikichi H, Aida J, Kondo K, Tsuboya T, Matsuyama Y, Subramanian SV, Kawachi I, 2016 Increased risk of dementia in the aftermath of the 2011 Great East Japan earthquake and tsunami. Proc. Natl. Acad. Sci. Unit. States Am 113, E6911–E6918. 10.1073/pnas.1607793113.

Jacobi CE, Mol GD, Boshuizen HC, Rupp I, Dinant HJ, Van den Bos GAM, 2003 Impact of socioeconomic status on the course of rheumatoid arthritis and on related use of health care services. Arthritis Rheum. 49, 567–573. 10.1002/art.11200. [PubMed: 12910565]

Jin X, Beguerie JR, Zhang W, Blizzard L, Otahal P, Jones G, Ding C, 2015 Circulating C reactive protein in osteoarthritis: a systematic review and meta-analysis. Ann. Rheum. Dis 74, 703–710. 10.1136/annrheumdis-2013-204494. [PubMed: 24363360]

Kessler RC, Andrew G, Colpe LJ, Hiripi E, Mroczek DK, Normand S-LT, Walters EE, Zaslavksy AM, 2002 Short screening scales to monitor population prevalences and trends in non-specific psychological distress. Psychol. Med 32, 959–976. 10.1017/s0033291702006074. [PubMed: 12214795]

Kondo K, 2016 Progress in aging epidemiology in Japan: the JAGES Project. J. Epidemiol 26, 331–336. 10.2188/jea.JE20160093. [PubMed: 27349200]

Kondo K, Rosenberg M, World Health Organization, 2018 Advancing universal health coverage through knowledge translation for healthy ageing: lessons learnt from the Japan Gerontological Evaluation Study. World Heal. Organ. 1–128.

Leigh JP, Fries JF, 1991 Occupation, income, and education as independent covariates of arthritis in four national probability samples. Arthritis Rheum. 34, 984–995. 10.1002/art.1780340808. [PubMed: 1859493]

Matsuyama Y, Aida J, Tsuboya T, Hikichi H, Kondo K, Kawachi I, Osaka K, 2017 Are lowered socioeconomic circumstances causally related to tooth loss? A natural experiment involving the 2011 Great East Japan Earthquake. Am. J. Epidemiol 186, 54–62. 10.1093/aje/kwx059. [PubMed: 28472254]

Matsuyama Y, Jürges H, Listl S, 2019 The causal effect of education on tooth loss: evidence from United Kingdom schooling reforms. Am. J. Epidemiol 188, 87–95. 10.1093/aje/kwy205. [PubMed: 30203091]

McLachlan KJJ, Gale CR, 2018 The effects of psychological distress and its interaction with socioeconomic position on risk of developing four chronic diseases. J. Psychosom. Res 109, 79–85. 10.1016/j.jpsychores.2018.04.004. [PubMed: 29680578]

McLaren L, 2007 Socioeconomic status and obesity. Epidemiol. Rev 29, 29–48. 10.1093/epirev/mxm001. [PubMed: 17478442]

Mehlum IS, Kristensen P, Kjuus H, Wergeland E, 2008 Are occupational factors important determinants of socioeconomic inequalities in musculoskeletal pain? Scand. J. Work. Environ. Health 34, 250–259. 10.5271/sjweh.1269. [PubMed: 18815713]

Miyagi Prefectural Government, 2019 Report of Damage by the Great East Japan Earthquake [in Japanese]. Miyagi Prefect. Gov.

O'Reilly SC, Muir KR, Doherty M, 2000 Occupation and knee pain: a community study. Osteoarthritis Cartilage 8, 78–81. 10.1053/joca.1999.0274. [PubMed: 10772236]

Patten SB, Williams JVA, Lavorato DH, Modgill G, Jetté N, Eliasziw M, 2008 Major depression as a risk factor for chronic disease incidence: longitudinal analyses in a general population cohort. Gen. Hosp. Psychiatr 30, 407–413. 10.1016/j.genhosppsych.2008.05.001.

Peeters GMEE, Alshurafa M, Schaap L, De Vet HCW, 2015 Diagnostic accuracy of self-reported arthritis in the general adult population is acceptable. J. Clin. Epidemiol 68, 452–459. 10.1016/j.jclinepi.2014.09.019. [PubMed: 25459981]

Punzi L, Galozzi P, Luisetto R, Favero M, Ramonda R, Oliviero F, Scanu A, 2016 Post-traumatic arthritis: overview on pathogenic mechanisms and role of inflammation. RMD Open, 10.1136/rmdopen-2016-000279.

Rothman KJ, Greenland S, Lash TL, 2008 Modern Epidemiology, third ed. Lippincott Williams & Wilkins, Philadelphia.

Schisterman EF, Cole SR, Platt RW, 2009 Overadjustment bias and unnecessary adjustment in epidemiologic studies. Epidemiology 20, 488–495. 10.1097/EDE.0b013e3181a819al. [PubMed: 19525685]

Scott KM, Von Korff M, Angermeyer MC, Benjet C, Bruffaerts R, Maria Haro J, Sanitari Sant Joan de Déu P, Boi de Llobregat S, Jean-Pierre Lépine S, Ormel J, Posada-Villa J, Tachimori H, Kessler RC, 2011 The association of childhood adversities and early onset mental disorders with adult onset chronic physical conditions. Arch. Gen. Psychiatr 68, 838–844. 10.1001/archgenpsychiatry.2011.77. [PubMed: 21810647]

Segerstrom SC, Miller GE, 2004 Psychological stress and the human immune system: a meta-analytic study of 30 years of inquiry. Psychol. Bull 130, 601–630. 10.1037/0033-2909.130.4.601. [PubMed: 15250815]

Shiba K, Hikichi H, Aida J, Kondo K, Kawachi I, 2019 Long-term associations between disaster experiences and cardiometabolic risk: a natural experiment from the 2011 Great East Japan Earthquake and Tsunami. Am. J. Epidemiol 188, 1109–1119. 10.1093/aje/kwz065. [PubMed: 30874714]

Theis KA, Roblin DW, Helmick CG, Luo R, 2018 Prevalence and causes of work disability among working-age U.S. adults, 2011–2013. NHIS. Disabil. Health J 11, 108–115. 10.1016/j.dhjo.2017.04.010. [PubMed: 28476583]

Tsuboya T, Aida J, Hikichi H, Subramanian SV, Kondo K, Osaka K, Kawachi I, 2016 Predictors of depressive symptoms following the Great East Japan earthquake: a prospective study. Soc. Sci. Med 161, 47–54. 10.1016/j.socscimed.2016.05.026. [PubMed: 27239707]

M.K Wada T, Ishine M, Kita T, Fujisawa M, 2003 Depression screening of elderly community-dwelling Japanese. J. Am. Geriatr. Soc 51, 1328–1329. 10.1046/j.1532-5415.2003.514207.x.

Wardle J, Waller J, Jarvis MJ, 2002 Sex differences in the association of socioeconomic status with obesity. Am. J. Publ. Health 92, 1299–1304. 10.2105/AJPH.92.8.1299.

Wilson-Genderson M, Heid AR, Pruchno R, 2018 Long-term effects of disaster on depressive symptoms: type of exposure matters. Soc. Sci. Med 217, 84–91. 10.1016/j.socscimed.2018.09.062 [PubMed: 30296694]

Wium-Andersen MK, Ørsted DD, Nielsen SF, Nordestgaard BG, 2013 Elevated C-reactive protein levels, psychological distress, and depression in 73131 individuals. JAMA Psychiatry 70, 176–184. 10.1001/2013.jamapsychiatry.102. [PubMed: 23266538]

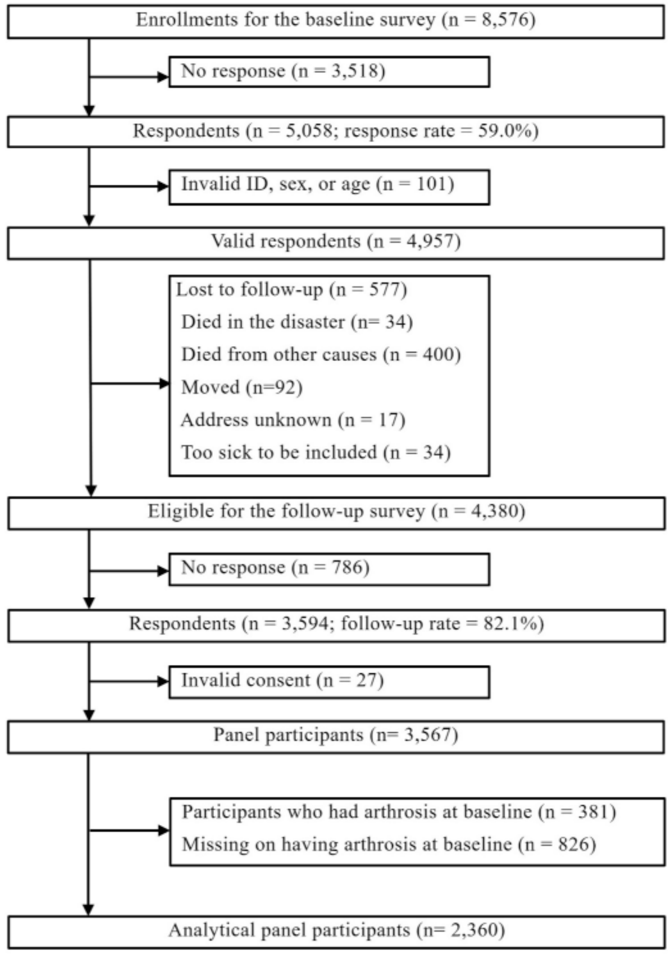

Fig. 1.
Recruitment and follow-up diagram (n = 2360).

Table 1

Demographics of participants and the development of arthritis after the 2011 Great East Japan Earthquake and Tsunami (n = 2360), Iwanuma, Japan, 2010–2013.

	Total number of participants	New-onset arthritis				*P*-value[b]
		No		Yes		
		n	%	n	%	
Subjective deterioration of economic circumstances						
No change/improved	1753	1693	76.5	60	63.2	<0.001
Became partially worse	389	363	16.4	26	27.4	
Became worse	167	158	7.1	9	9.5	
Missing	51	51	–	0	–	
Housing damage						
No damage	940	912	41.4	28	30.1	<0.001
Partial	981	946	42.9	35	37.6	
Minor	176	156	7.1	20	21.5	
Major	95	87	4.0	8	8.6	
Destroyed	104	102	4.6	2	2.2	
Missing	64	62	–	2	–	
Age group (years)						
65–69	695	665	29.4	30	31.6	0.91
70–74	677	650	28.7	27	28.4	
75–79	519	499	22.0	20	21.1	
80–84	315	301	13.3	14	14.7	
85–	154	150	6.6	4	4.2	
Sex						
Men	1057	1030	45.5	27	28.4	0.002
Women	1303	1235	54.5	68	71.6	
Educational attainment						
≤9	815	780	34.4	35	36.8	0.49
10–12	986	950	41.9	36	37.9	
≥13	472	454	20.0	18	19.0	

	Total number of participants	New-onset arthritis				*P*-value[b]
		No		Yes		
		n	%	n	%	
Missing	87	81	3.6	6	6.3	
Tertile of pre-disaster income level						
Low	705	685	30.2	20	21.1	0.24
Middle	621	591	26.1	30	31.6	
High	611	586	25.9	25	26.3	
Missing	423	403	17.8	20	21.1	
Osteoporosis/traumatic injuries/fractures before disaster						
No	2184	2098	92.6	86	90.5	0.45
Yes	176	167	7.4	9	9.5	
Body mass index before disaster						
<18.5	108	101	4.5	7	7.4	0.46
18.5–24.9	1452	1401	61.9	51	53.7	
25.0–29.9	566	541	23.9	25	26.3	
≥30.0	59	56	2.5	3	3.2	
Missing	175	166	7.3	9	9.5	
Smoking status before disaster						
Never	1302	1242	54.8	60	63.2	0.14
Quit	641	625	27.6	16	16.8	
Current	219	2109.3		9	9.5	
Missing	198	1888.3		10	10.5	
Depressive symptoms before disaster						
None	1370	1323	58.4	47	49.5	0.05
Moderate	488	463	20.4	25	26.3	
Severe	184	171	7.6	13	13.7	
Missing	318	308	13.6	10	10.5	
Loss of loved ones in disaster						
Loss	611	579	25.6	32	33.7	0.08
No loss	1749	1686	74.4	63	66.3	
Disruption of access to orthopedics after disaster						

	Total number of participants	New-onset arthritis				*P*-value[b]
		No		Yes		
		n	%	n	%	
No	2311	2226	98.3	85	89.5	<0.001
Yes	49	39	1.7	10	10.5	
Psychological distress after disaster						
None	1299	1258	55.5	41	43.2	0.05
Moderate	842	798	35.2	44	46.3	
Severe	219	209	9.2	10	10.5	
Change in body mass index between baseline and follow-up	2126	2043	−0.11[a]	83	−0.09[a]	–

Because of rounding, percentages do not add up to exactly 100%.

[a]Mean values are represented.

[b]Chi-squared test or Fisher's exact test was performed.

Table 2

Subjective deterioration of economic circumstances and the development of arthritis (n = 2309)[a], Iwanuma, Japan, 2010–2013.

	OLS (without IV)			IV model[b]		
	Coef.	95% CI		Coef.	95% CI	
Subjective deterioration of economic circumstances	**0.02**	**0.001**	**0.03**	**0.08**	**0.03**	**0.12**
Age group (years)						
65–69	Reference			Reference		
70–74	0.00	−0.02	0.02	0.00	−0.02	0.02
75–79	−0.01	−0.03	0.02	0.00	−0.02	0.03
80–84	0.00	−0.03	0.03	0.01	−0.02	0.04
85–	−0.02	−0.05	0.01	−0.01	−0.04	0.02
Sex						
Men	Reference					
Women	**0.79**	**0.12**	**1.45**	**0.03**	**0.01**	**0.06**
Educational attainment						
≤ 9	Reference			Reference		
10–12	−0.01	−0.03	0.01	0.00	−0.02	0.02
≥ 13	0.00	−0.03	0.02	0.01	−0.02	0.03
Missing	0.03	−0.04	0.09	0.03	−0.04	0.09
Tertile of pre-disaster income level						
Low	Reference			Reference		
Middle	**0.03**	**0.01**	**0.05**	**0.04**	**0.02**	**0.06**
High	**0.02**	**0.002**	**0.04**	**0.03**	**0.01**	**0.06**
Missing	0.02	−0.01	0.04	0.02	−0.01	0.05
Osteoporosis/traumatic injuries/fractures before disaster						
No	Reference			Reference		
Yes	0.00	−0.04	0.03	−0.01	−0.04	0.03
Body mass index before disaster						
18.5–24.9	Reference			Reference		
<18.5	0.03	−0.02	0.08	0.03	−0.02	0.08
25.0–29.9	0.01	−0.01	0.03	0.01	−0.01	0.03
≥ 30.0	0.01	−0.05	0.07	0.02	−0.04	0.08
Missing	0.01	−0.03	0.05	0.01	−0.03	0.05
Smoking status before disaster						
Never	Reference			Reference		
Quit	0.00	−0.02	0.02	0.00	−0.02	0.02
Current	0.01	−0.02	0.04	0.02	−0.02	0.05
Missing	0.00	−0.04	0.04	0.00	−0.04	0.03
Depressive symptoms before disaster						
None	Reference			Reference		
Moderate	0.02	−0.01	0.04	0.01	−0.01	0.03

	OLS (without IV)			IV model[b]		
	Coef.	**95% CI**		**Coef.**	**95% CI**	
Severe	0.03	−0.01	0.07	0.02	−0.02	0.06
Missing	−0.01	−0.03	0.01	−0.01	−0.04	0.01

Statistical significance at $P < 0.05$ is indicated in **bold**. Missing covariates were treated as the dummy category.

OLS: Ordinary least squares, Coef.: Nonstandardized coefficient, CI: Confidence interval, IV: Instrumental variable.

[a]We excluded 51 participants who lacked information regarding subjective deterioration of economic circumstances.

[b]*F*-statistic in the first stage of IV analysis = 197.7.

Table 3

Housing damage and the development of arthritis (n = 2296)[a], Iwanuma, Japan, 2010–2013.

	OLS (without IV)			IV model[b]		
	Coef.	95% CI		Coef.	95% CI	
Housing damage	**0.01**	**0.002**	**0.02**	**0.02**	**0.01**	**0.04**
Age group (years)						
65–69	Reference			Reference		
70–74	0.00	−0.02	0.02	0.00	−0.02	0.02
75–79	−0.01	−0.03	0.02	0.00	−0.03	0.02
80–84	0.00	−0.03	0.03	0.00	−0.03	0.03
85–	−0.02	−0.05	0.01	−0.02	−0.05	0.01
Sex						
Men	Reference			Reference		
Women	**0.03**	**0.005**	**0.05**	**0.03**	**0.01**	**0.05**
Educational attainment						
≤9	Reference			Reference		
10–12	0.00	−0.03	0.02	0.00	−0.02	0.02
≥13	0.00	−0.02	0.02	0.00	−0.02	0.03
Missing	0.03	−0.04	0.09	0.03	−0.04	0.09
Tertile of pre-disaster income level						
Low	Reference			Reference		
Middle	**0.03**	**0.01**	**0.05**	**0.03**	**0.01**	**0.05**
High	**0.02**	**0.001**	**0.04**	**0.02**	**0.002**	**0.04**
Missing	0.02	−0.01	0.04	0.02	−0.01	0.04
Osteoporosis/traumatic injuries/fractures before disaster						
No	Reference			Reference		
Yes	0.00	−0.04	0.04	0.00	−0.04	0.04
Body mass index before disaster						
18.5–24.9	Reference			Reference		
<18.5	0.03	−0.02	0.08	0.03	−0.02	0.08
25.0–29.9	0.01	−0.01	0.03	0.01	−0.01	0.03
≥30.0	0.01	−0.05	0.07	0.01	−0.05	0.07
Missing	0.01	−0.03	0.05	0.01	−0.03	0.05
Smoking status before disaster						
Never	Reference			Reference		
Quit	0.00	−0.02	0.02	0.00	−0.02	0.02
Current	0.01	−0.02	0.04	0.01	−0.02	0.04
Missing	0.00	−0.04	0.03	−0.01	−0.04	0.03
Depressive symptoms before disaster						
None	Reference			Reference		
Moderate	0.02	0.00	0.04	0.02	−0.003	0.04
Severe	0.04	−0.003	0.07	0.04	−0.002	0.07

	OLS (without IV)			IV model[b]		
	Coef.	**95% CI**		**Coef.**	**95% CI**	
Missing	−0.01	−0.03	0.02	−0.01	−0.04	0.01

Statistical significance at $P < 0.05$ is indicated in **bold**. Missing covariates were treated as the dummy category.

OLS: Ordinary least squares, Coef.: Nonstandardized coefficient, CI: Confidence interval, IV: Instrumental variable.

[a]We excluded 64 participants who lacked information regarding housing damage.

[b]*F*-statistic in the first stage of IV analysis = 733.0.

Table 4

Reduction in coefficients by loss of loved ones in disaster, disruption of access to orthopedics after disaster, and psychological distress after disaster (subjective deterioration of economic circumstances) (n = 2309).

	Ordinary least squares regression (without IV)							IV regression						
	Model 1[a]			Model 2[b]			% of reduction	Model 1[a]			Model 2[b]			% of reduction
	Coef.	95% CI		Coef.	95% CI			Coef.	95% CI		Coef.	95% CI		
Subjective deterioration of economic circumstances	**0.02**	**0.001**	**0.03**	**0.02**	**0.0001**	**0.03**	−6.34%	**0.08**	**0.03**	**0.12**	**0.08**	**0.03**	**0.12**	0.36%
Loss of loved ones in disaster														
Loss											Reference			
No loss				−0.01	−0.03	0.01					0.001	−0.02	0.02	
Subjective deterioration of economic circumstances	**0.02**	**0.001**	**0.03**	0.01	−0.002	0.03	−19.84%	**0.08**	**0.03**	**0.12**	**0.07**	**0.03**	**0.11**	−5.33%
Disruption of access to orthopedics after disaster														
No											Reference			
Yes				**0.17**	**0.05**	**0.29**					**0.15**	**0.03**	**0.27**	
Subjective deterioration of economic circumstances	**0.02**	**0.001**	**0.03**	**0.02**	**0.0001**	**0.03**	−6.22%	**0.08**	**0.03**	**0.12**	**0.07**	**0.03**	**0.12**	−0.15%
Psychological distress after disaster														
None											Reference			
Moderate				0.01	−0.005	0.03					0.00	−0.02	0.02	
Severe				0.00	−0.03	0.03					−0.01	−0.05	0.02	
Subjective deterioration of economic circumstances[c]	0.02	−0.001	0.03	0.02	−0.001	0.03	−0.13%	**0.07**	**0.03**	**0.12**	**0.07**	**0.03**	**0.12**	0.12%
Change in BMI between baseline and follow-up (continuous)				0.00	0.00	0.00					−0.01	−0.01	0.00	

Statistical significance at $P < 0.05$ is indicated in **bold**. Missing covariates were treated as the dummy category.

Coef.: Nonstandardized coefficient, CI: Confidence interval, IV: Instrumental variable.

[a] Age, sex, educational attainment, pre-disaster income level, osteoporosis/traumatic injuries/fractures before disaster, body mass index (BMI) before disaster, smoking status before disaster, and depressive symptoms before disaster were adjusted.

[b] Potential mediators (loss of loved ones in disaster, disruption of access to orthopedics after disaster, or psychological distress after disaster) were added to Model 1.

[c] The number of participants was 2087 as participants whose BMI at baseline and follow-up were missing were excluded.

Table 5

Reduction in coefficients by loss of loved ones in disaster, disruption of access to orthopedics after disaster, and psychological distress after disaster (housing damage) (n = 2296).

	Ordinary least squares (without IV)							IV regression						
	Model 1[a]			Model 2[b]			% of reduction	Model 1[a]			Model 2[b]			% of reduction
	Coef.	95% CI		Coef.	95% CI			Coef.	95% CI		Coef.	95% CI		
Housing damage	**0.01**	**0.002**	**0.02**	**0.01**	**0.001**	**0.02**	−6.00%	**0.02**	**0.01**	**0.04**	**0.02**	**0.01**	**0.04**	−0.58%
Loss of loved ones in disaster														
Loss														
No loss				−0.01	−0.03	0.01					−0.001	−0.02	0.02	
Housing damage	**0.01**	**0.002**	**0.02**	**0.01**	**0.001**	**0.02**	−14.81%	**0.02**	**0.01**	**0.04**	**0.02**	**0.01**	**0.04**	−6.07%
Disruption of access to orthopedics after disaster														
No														
Yes				**0.17**	**0.06**	**0.29**					**0.17**	**0.05**	**0.29**	
Housing damage	**0.01**	**0.002**	**0.02**	**0.01**	**0.001**	**0.02**	−5.20%	**0.02**	**0.01**	**0.04**	**0.02**	**0.01**	**0.04**	−2.62%
Psychological distress after disaster														
None														
Moderate				0.01	−0.004	0.03					0.01	−0.01	0.03	
Severe				0.01	−0.03	0.04					0.00	−0.03	0.04	
Housing damage[c]	**0.01**	**0.001**	**0.02**	**0.01**	**0.001**	**0.02**	−0.24%	**0.02**	**0.01**	**0.04**	**0.02**	**0.01**	**0.04**	−0.08%
Change in BMI between baseline and follow-up (continuous)				0.00	−0.004	0.01					0.00	−0.004	0.01	

Statistical significance at $P < 0.05$ is indicated in **bold**. Missing covariates were treated as the dummy category.

Coef.: Nonstandardized coefficient, CI: Confidence interval, IV: Instrumental variable.

[a]Age, sex, educational attainment, pre-disaster income level, osteoporosis/traumatic injuries/fractures before disaster, body mass index (BMI) before disaster, smoking status before disaster, and depressive symptoms before disaster were adjusted.

[b]Potential mediators (loss of loved ones in disaster, disruption of access to orthopedics after disaster, or psychological distress after disaster) were added to Model 1.

[c]The number of participants was 2078 as participants whose BMI at baseline and follow-up were missing were excluded.