

# Effects of different living conditions on the risk of osteoporosis in Chinese community-dwelling elderly: a 3-year cohort study

Xing Yu<sup>1,\*</sup>, Yuanyuan Zhang<sup>2,\*</sup>, Peipei Han<sup>3</sup>,  
Liyuan Fu<sup>2</sup>, Xiaoyu Chen<sup>2</sup>, Lin Hou<sup>2</sup>,  
Peiyu Song<sup>2</sup>, Yong Zhao<sup>3</sup> and Qi Guo<sup>1</sup> 

## Abstract

**Objective:** Osteoporosis can lead to bone fragility and an increased risk of bone fracture with resultant high morbidity and mortality. Living alone has been associated with various mental and physical health problems. However, the risk of osteoporosis among individuals with different living conditions and changing living conditions is unclear. We examined the risk of osteoporosis in different living conditions over a 3-year period in community-dwelling suburban elderly Chinese.

**Methods:** This study involved 288 elderly Chinese suburb-dwelling participants with no documented history of osteoporosis. All were aged  $\geq 60$  years (mean,  $65.6 \pm 3.75$  years; 157 men). A quantitative ultrasound scan of the calcaneus with a T score of  $< -2.5$  was used to identify a high risk of osteoporosis.

**Results:** In total, 54.2% of participants were determined to have a high risk of osteoporosis (male, 51.6%; female, 57.3%). People who had always lived alone had a significantly higher risk of osteoporosis, even after adjusting for potential confounders. A change from living alone to living with others had no significant impact on the risk of osteoporosis.

**Conclusion:** Our results indicate that living alone is associated with a high risk of osteoporosis. Thus, people who live alone may need regular bone tests to avoid adverse events.

<sup>1</sup>Department of Rehabilitation Medicine, Shanghai University of Medicine and Health Sciences Affiliated Zhoupu Hospital, Shanghai, China

<sup>2</sup>Department of Rehabilitation Medicine, Tianjin Medical University, Tianjin, China

<sup>3</sup>Department of Rehabilitation Medicine, Shanghai University of Medicine and Health Sciences, Shanghai, China

\*These authors contributed equally to this work and should be considered co-first authors.

## Corresponding author:

Qi Guo, College of Rehabilitation Sciences, Shanghai University of Medicine and Health Sciences, 279 Zhouzhu Highway, Pudong New Area, Shanghai 201318, China.  
Email: guoqijp@gmail.com



**Keywords**

Elderly people, living alone, osteoporosis, suburb-dwelling, risk factor, T score

Date received: 25 December 2019; accepted: 29 June 2020

**Introduction**

Osteoporosis leads to many serious health problems that severely decrease patients' quality of life and inevitably increase morbidity and mortality rates.<sup>1</sup> In China, osteoporosis affects more than one-third of people aged  $\geq 50$  years, hereafter referred to as the elderly population.<sup>2</sup> Consequently, osteoporosis is becoming a major public health issue, and it is important to prevent its development and occurrence. Research has shown that many physiological and pathological factors are related to the prevalence of osteoporosis, such as female sex, estrogen deficiency, low body weight and body mass index (BMI), and smoking habits.<sup>3</sup> One's living arrangements are critical to his or her health in old age.<sup>4</sup> However, the impact of environmental factors on osteoporosis remains unclear. Therefore, we became interested in examining the relationship between environmental factors and osteoporosis.

The number of elderly individuals living alone is rapidly increasing in most developing countries, especially in rural areas.<sup>5</sup> Elderly individuals living alone are more likely to report poor health-related quality of life, depression, smoking, drinking, and poor nutrient intake, all of which may increase the risk of osteoporosis.<sup>6,7</sup> A cross-sectional Korean study showed that residing in rural areas was significantly associated with osteoporosis in women living alone.<sup>8</sup> Another cross-sectional study showed that individuals living alone in rural areas had significantly lower bone mineral density (BMD) of the lumbar spine,

which may lead to an increased risk of osteoporosis, than individuals living in households with two or more people.<sup>7</sup> Conversely, a cross-sectional study showed that patients with dementia living alone had significantly fewer impairments in their activities of daily living than those living with other people because they needed to take on more housework, which may prevent the occurrence of osteoporosis.<sup>9</sup> Another cross-sectional study revealed that elderly individuals living alone had a better functional status, which may lead to a decreased risk of osteoporosis, than elderly individuals who were unmarried and living with their children.<sup>10</sup> Several studies have shown no significant differences in physical activity between individuals living alone and those living with other people.<sup>7,8</sup> Above all, the association between living alone and osteoporosis remains inconsistent, and few cohort studies have explored the relationship between osteoporosis and living alone among elderly populations in China. Therefore, we investigated the effects of living alone on the incidence of osteoporosis among elderly individuals in a suburban community of China.

Considering the lack of appropriate and consistent evidence regarding the association between living alone and osteoporosis, the objective of this study was to determine the risk of osteoporosis over a 3-year period among community suburban-dwelling elderly Chinese people who were living alone. We conducted this survey in an elderly Chinese community suburban-dwelling population because  $>70\%$  of Chinese

elderly individuals have lived in suburban areas since 2012.<sup>11</sup>

## Methods

### *Study participants*

Our study population comprised community suburban-dwelling elderly individuals from Chadian, Tianjin, China who had joined the national free physical examination program. Participants with the following conditions were excluded from the study: (1) those whose medical record or history showed diseases that may affect bone or calcium metabolism (e.g., a previous diagnosis of osteoporosis, osteomalacia, or osteogenesis imperfecta), (2) those with a foot injury that prevented BMD testing, (3) those who were taking a drug that may interfere with bone or calcium metabolism (e.g., estrogen, calcitonin, diphosphonate), (4) inability to communicate with interviewers or to grant informed consent, and (5) inability to stand for measurement of body composition, weight, and height. The cohort was invited to attend repeat questionnaire interviews and physical measurements at 12, 24, and 36 months during the 3-year period following the baseline investigation. All participants provided informed consent prior to participation. Our study was approved by the ethics committee of our university (approval no. ChiCTR1800016308), and all participants agreed to participate in the survey and gave informed written consent for data collection.

### *Covariates*

We interviewed all participants in person using a questionnaire from our previous study.<sup>12</sup> We collected data on the participants' sociodemographics and behavioral characteristics, including age, sex, education level, smoking and drinking habits, living

conditions, history of falls, and depression. Depressive symptoms were assessed using the Geriatric Depression Scale.<sup>13</sup> We also reviewed whether the participants had chronic medical conditions (e.g., osteoarthritis). Physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ)<sup>14</sup> and is represented by 75% quartiles. Performance-based assessments, including the 4-meter walk test and the Timed Up and Go Test (TUGT), were also conducted. The prevalence of specific medical conditions such as hypertension, hyperlipidemia, stroke, coronary heart disease, and kidney disease was established using standardized criteria that combined information from the participant's history of physical illness evaluated by his or her response (yes or no) to questions, the physician's diagnosis, and whether the participant was taking corresponding medication or undergoing other treatment now or in the past.

### *Assessment of high risk of osteoporosis*

Bone health was assessed using a gel-based quantitative ultrasound device (OsteoPro UBD2002A; B.M.Tech Worldwide Co., Ltd., Seoul, Korea) to determine the T score of the calcaneus based on the World Health Organization criteria.<sup>15</sup> The short-term in vivo coefficient of variation for the device was <2.5%. Three measurements with repositioning were taken, and the averaged values were used in the analysis. Calibration was performed at the beginning of each screening session. The measurement was able to be started when the SOS error was within the range of  $\pm 10$ . A T score of  $< -2.5$  was considered to indicate high risk of osteoporosis.<sup>16</sup>

### *Statistical analysis*

The participants' baseline characteristics are reported as median (25th–75th

percentiles) for the IPAQ; all other continuous variables are presented as mean and standard deviation. Classification variables are reported as percentages. Differences in the participants' characteristics according to their osteoporosis status were analyzed using the t-test,  $\chi^2$  test, and rank sum test. Continuous variables were compared using analysis of variance, and each P-value reflecting the significance of each head-to-head comparison was obtained by the Student–Newman–Keuls test. Differences in categorical variables and differences between groups were assessed by the  $\chi^2$  test, and the test standard was corrected.

According to the trend test of Schoenfeld residuals, the correlation between partial residuals and time rank was not significant (Pearson correlation, 0.074); therefore, this study was suitable for Cox analysis. Multivariable Cox proportional regression was used to examine the effect of different living conditions on the risk of osteoporosis during the 3-year follow-up. Crude rates were not adjusted. Model 1 was adjusted for sex, age, and BMI. Model 2 was adjusted for Model 1 variables in addition to grip, walking speed, TUGT, IPAQ, cardiovascular diseases, marital status, illiteracy, history of smoking and drinking habits, and depression. All statistical analyses were performed using SPSS version 19.0 (IBM Corp., Armonk, NY, USA), and P-values of  $<0.05$  were considered statistically significant.

## Results

### Baseline characteristics

A total of 1036 individuals aged  $\geq 60$  years in the study area joined the national free physical examination program from May 2013. Forty-four individuals were excluded (15 with underlying diseases that were likely to affect bone or calcium metabolism and 29 who failed to undergo a physical

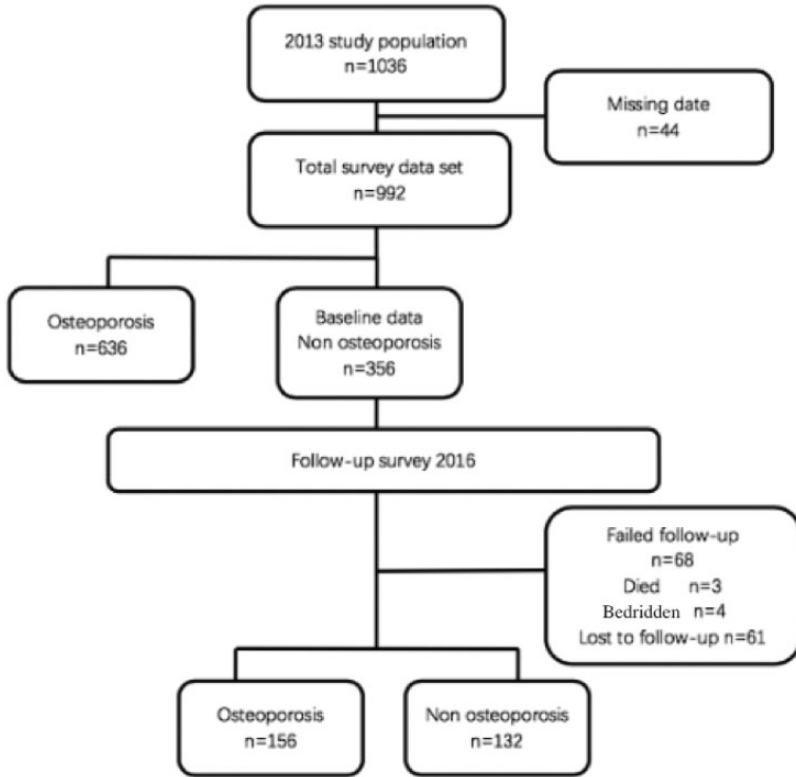
examination). During the 3-year follow-up, 3 participants died, 4 became bedridden, and 61 were lost to follow-up; these 68 participants were excluded from the study, as shown in Figure 1. The final study population comprised 288 participants.

Table 1 presents the characteristics of all 288 participants according to their osteoporosis risk status at the 3-year follow-up. Compared with participants who had developed a new-onset high risk of osteoporosis after 3 years, participants without a risk of osteoporosis were more likely to live alone ( $P < 0.001$ ) and have a lower BMI ( $P = 0.047$ ), while people with a high risk of osteoporosis were more likely to have depression ( $P = 0.014$ ), lower physical activity ( $P = 0.013$ ), and more sedentary time ( $P = 0.046$ ).

### Characteristics according to living status at 3-year follow-up

Table 2 shows the characteristics of participants with different living statuses during the 3-year follow-up. People who had always lived alone (PA) were significantly older ( $P < 0.001$ ), had a lower balance ability as estimated by the TUGT ( $P < 0.001$ ), and were more likely to have depression than people who had always or ever lived with others (PO and PA-PO, respectively). Additionally, the PA group had lower grip strength ( $P = 0.045$ ) than the PO group and had a lower walking speed ( $P = 0.023$ ), had a higher risk of osteoporosis ( $P = 0.023$ ), and were more likely to be widowed ( $P < 0.001$ ) than the PA-PO group.

Table 3 shows the results of the Cox analysis that was performed to examine the effects of different living conditions on the risk of osteoporosis. In the adjusted Model 2, the change from living alone to living with others did not significantly increase the risk of osteoporosis (hazard ratio (HR), 0.755; 95% confidence interval



**Figure 1.** Flow chart of selection of study participants.

(CI), 0.179–9.804). However, individuals who had always lived alone (HR, 2.659; 95% CI, 1.124–6.283;  $P=0.026$ ) or who had transitioned from living with others to living alone (HR, 1.988; 95% CI, 1.015–3.891;  $P=0.045$ ) had a significantly increased risk of osteoporosis.

## Discussion

We assessed the differences in the baseline characteristics of individuals with a high risk of osteoporosis after 3 years among an elderly population living in the suburbs in China. The proportions of participants with osteoporosis were 22.2% after 1 year, 38.8% after 2 years, and 54.2% after 3 years. The risk of osteoporosis after 1 to 2

years was about 20% to 40%, which is consistent with previous research, and the risk of osteoporosis was higher in women than in men, which is also consistent with previous research.<sup>2,7,8</sup> A possible reason for the higher rates in women than men is that the estrogen deficiency associated with menopause or oophorectomy may lead to a rapid reduction of BMD in women, while the mechanisms of age-related testosterone deficiency and bone loss are not sudden and the amount of total testosterone does not change drastically in men; additionally, the changes in bioavailability of testosterone have a less pronounced effect on bone mass than in women.<sup>2,17</sup> Our baseline data showed that patients with a high risk of osteoporosis had lower physical activity

**Table 1.** Baseline characteristics of study participants according to presence of osteoporosis at 3-year follow-up.

Characteristic	Normal (n = 132)	Osteoporosis (n = 156)	P-value
Male/female	76/56	81/75	0.337
Age, years	66.19 ± 4.88	65.15 ± 3.10	0.334
BMI, kg/m <sup>2</sup>	25.55 ± 2.79	26.73 ± 3.75	0.047
Grip, kg	28.33 ± 8.85	26.47 ± 8.19	0.379
4MWT, m/s	1.10 ± 0.31	1.10 ± 0.28	0.986
TUGT, seconds	9.11 ± 4.67	7.78 ± 4.11	0.099
IPAQ, MET-minutes/week	2394 (894, 6132)	1848 (644, 4185)	0.245
High level, %	43.4	19.8	0.015
Moderate level, %	30.5	11.9	0.043
Low level, %	26.1	68.3	0.013
Sedentary time, hours	3.05 ± 1.75	3.68 ± 2.02	0.046
Fall history, %	10.1	10.3	0.970
Smoking, %	33.3	31.6	0.789
Drinking, %	14.1	16.2	0.669
Widowed, %	22.7	31.9	0.546
Living alone, %	58.6	17.1	<0.001
Illiteracy, %	40.4	39.3	0.871
Farming, %	84.8	83.8	0.827
Diabetes, %	23.2	13.7	0.069
Hypertension, %	50.5	39.3	0.099
Hyperlipidemia, %	9.1	4.3	0.152
Heart disease, %	17.2	19.7	0.639
Peptic ulcer, %	6.1	4.3	0.552
Stroke, %	3.0	6.8	0.205
Gout, %	1.0	2.6	0.399
Osteoarthritis, %	23.2	27.4	0.489
Kidney disease, %	3.0	3.4	0.872
Thyroid disease, %	0.0	0.9	0.357
Depression, %	2.0	10.3	0.014

BMI, body mass index; 4MWT, 4-meter walk test; TUGT, Timed Up and Go Test; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent of task. Data are presented as n, mean ± standard deviation, or median (25th–75th percentiles).

levels, a higher sedentary time, and a higher prevalence of depression, which is consistent with previous studies that these risk factors may increase the prevalence of osteoporosis.<sup>18,19</sup>

We assessed the risk of osteoporosis among elderly Chinese individuals living alone over a 3-year period in a community-dwelling suburban population, and we found that individuals who were living alone at baseline had a lower risk of

osteoporosis than people living with others. However, this is inconsistent with previous research.<sup>7,8</sup> To analyze the relationship between different living conditions and the risk of osteoporosis in detail, we compared the characteristics of different living state parameters 3 years later by grouping. We found that many people changed their living status during the 3 years. Some people changed from living alone to living with others, while others changed from

**Table 2.** Characteristics of participants with different living statuses at 3-year follow-up.

Characteristic	PO (n = 108)	PA-PO (n = 80)	PO-PA (n = 76)	PA (n = 24)	P-value
Male/female, %	45.8/27.5	27.4/28.2	21.6/32.1 <sup>a</sup>	5.1/12.2 <sup>a</sup>	0.003
Age, years	68.09 ± 5.24	67.17 ± 4.45	69.11 ± 5.57	73.63 ± 6.46 <sup>a,b,c</sup>	<0.001
BMI, kg/m <sup>2</sup>	24.78 ± 3.53	23.61 ± 4.55	23.64 ± 2.96	23.45 ± 4.25	0.126
Grip, kg	25.34 ± 8.38 <sup>d</sup>	21.80 ± 2.92	24.02 ± 9.08	20.21 ± 8.75 <sup>a</sup>	0.045
4MWT, m/s	0.98 ± 0.19	1.10 ± 0.15	0.95 ± 0.20	0.87 ± 0.20 <sup>a,b</sup>	0.023
TUGT, seconds	8.67 ± 2.28	7.73 ± 1.21	9.38 ± 2.62	10.98 ± 4.15 <sup>a,b,c</sup>	<0.001
IPAQ, MET-minutes/week	2196 (896, 6492)	2053 (791, 5932)	1915 (581, 4704)	1385 (595, 4053)	0.339
High level	73.5	67.2	51.9	41.1	0.291
Moderate level	9.2	17.5	29.6	29.4	0.134
Low level	17.3	15.3	18.5	29.4	0.233
Widowed, %	2.4	3.5	67.8 <sup>a,b</sup>	100 <sup>a,b</sup>	<0.001
Osteoporosis, %	45.9	44.7	68.3	78.9 <sup>a,b</sup>	0.023
Fall history, %	15.2	0.0	19.4	10.5	0.593
Smoking, %	26.9	50.0	33.3	31.6	0.511
Drinking status, %	25.6	16.7	30.6	15.8	0.551
Illiteracy, %	57.5	50.0	61.1	47.4	0.774
Farming, %	64.4	83.3	75.0	64.8	0.467
Diabetes, %	11.9	0.0	8.3	0.0	0.296
Hypertension, %	48.7	16.7	47.2	47.4	0.484
Hyperlipidemia, %	13.5	0.0	19.4	5.3	0.370
Heart disease, %	23.4	33.3	22.2	31.6	0.794
Peptic ulcer, %	3.6	16.7	2.8	10.5	0.171
Stroke, %	5.3	0.0	2.8	10.5	0.607
Gout, %	0.5	16.7	0.0	0.0	0.428
Osteoarthritis, %	10.9	33.3	8.3	15.8	0.298
Kidney disease, %	2.3	0.0	2.8	0.0	0.889
Thyroid disease, %	1.3	0.0	0.0	0.0	0.854
Depression, %	4.8	0.0 <sup>c</sup>	8.3 <sup>b</sup>	33.3 <sup>a,b,c</sup>	0.017

BMI, body mass index; 4MWT, 4-meter walk test; TUGT, Timed Up and Go Test; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent of task; PO, people living with others; PA-PO, people living alone at baseline, living with others 3 years later; PO-PA, people living with others at baseline, living alone 3 years later; PA, people living alone.

<sup>a</sup>P < 0.05 versus group PO, <sup>b</sup>P < 0.05 versus group PA-PO, <sup>c</sup>P < 0.05 versus group PO-PA.

living with others to living alone. People who changed from living with others to living alone had a higher prevalence of depression ( $P = 0.017$ ) and were more likely to be widowed ( $P < 0.001$ ) than those who lived with others. People who changed from living alone to living with others were younger ( $P < 0.001$ ), had a higher walking speed ( $P = 0.023$ ), had greater balance ability ( $P < 0.001$ ), and had a lower prevalence of depression ( $P = 0.017$ ) than those who had been living alone. This may indicate that many people who were living alone at baseline had the ability to

take on their own living situation and therefore have a higher physical activity ( $P = 0.015$ ) and thus a lower risk of osteoporosis.<sup>20</sup> The influence of living alone in the short term was no longer obvious with the change of living conditions, which is similar to previous research.<sup>21</sup> Therefore, timely adjustments to the negative impact of living conditions, such as bad habits and other adverse effects that may occur when living alone, can improve morbidity.

The Cox analysis that was performed to examine the effects of different living conditions on the risk of osteoporosis showed



**Table 3.** Multivariate Cox proportional regression of different living statuses of participants with osteoporosis.

Variable	Crude		Adjusted Model 1		Adjusted Model 2	
	HR (95% CI)	P	HR (95% CI)	P	HR (95% CI)	P
PO	Reference		Reference		Reference	
PA-PO	1.416 (0.350–5.757)	0.626	1.325 (0.179–9.804)	0.783	0.755 (0.179–9.804)	0.782
PO-PA	2.110 (1.104–4.032)	0.024	2.033 (1.035–3.984)	0.039	1.988 (1.015–3.891)	0.045
PA	3.003 (1.319–6.849)	0.009	2.907 (1.274–6.622)	0.011	2.659 (1.124–6.283)	0.026

Crude rates were unadjusted.

HR, hazard ratio; CI, confidence interval; PO, people living with others; PA-PO, people living alone at baseline, living with others 3 years later; PO-PA, people living with others at baseline, living alone 3 years later; PA, people living alone.

Model 1 was adjusted for sex, age, and body mass index.

Model 2 was adjusted for Model 1 variables in addition to grip, walking speed, Timed Up and Go Test, International Physical Activity Questionnaire, cardiovascular diseases, marital status, illiteracy, history of smoking and drinking habits, and depression.

that a change from living alone to living with others did not have a significant negative impact on the risk of osteoporosis. However, individuals who had been living alone ( $P=0.026$ ) or who had transitioned from living with others to living alone ( $P=0.045$ ) had a significantly increased risk of osteoporosis, suggesting that living alone seems to increase the risk of osteoporosis, which is consistent with previous studies.<sup>7,8</sup> People who had been living alone had a higher incidence of depression than others ( $P=0.017$ ), which may have been due to a lack of social activities, a lack of social support, and malnutrition.<sup>7,17</sup> In contrast, people who changed from living alone to living with other people had better physical conditions and a lower incidence of depression (0.0% vs. 33.3%, respectively;  $P=0.017$ ), probably because those who had always lived alone had to live alone because of widowhood. People who changed from living alone to living with other people had a lower incidence of depression than those who had always lived alone, indicating that the state of residence may affect the incidence of depression through the nutritional status and social support, thus affecting the risk of osteoporosis. These findings are consistent with

previous studies.<sup>7,8,22</sup> Widowhood has been previously associated with an increased risk of adverse cardiovascular events and mortality because of living alone and having reduced social support.<sup>23–25</sup>

We compared the participants' baseline characteristics by grouping those living alone and found that people who lived alone were older and more likely to develop diabetes. A model study predicting the risk of osteoporosis through BMI and age showed that these age groups had the same level of risk<sup>26</sup> (living alone vs. living with someone,  $67.22 \pm 5.98$  vs.  $65.77 \pm 4.3$ , respectively;  $P=0.06$ ). In the baseline grouping of BMD status after 3 years, the difference between these two age groups was not significant. In some studies that investigated the relationship between BMD and diabetes, type 2 diabetes showed a possible association with spongy bone lesions, but local BMD was elevated.<sup>27,28</sup> According to the current status of living in rural China, people with better physical conditions might feel more comfortable living alone, especially when the elderly in the community engage in more physical and social activities,<sup>9</sup> which will reduce the risk of osteoporosis.<sup>30,31</sup>



This study was conducted by investigating a uniquely defined suburban population of elderly individuals living in an independent geographic area with small population mobility, and the characteristics of this population may therefore differ from those in other areas. This study had some limitations. All participants in this study were relatively healthy because we did not include participants who were unable to participate in the free annual national medical examination (such as those who were bedridden or had serious illness). Therefore, our results may actually underestimate the risk of osteoporosis and its associated health effects. However, statistically significant differences between participants with and without a high risk of osteoporosis were still observed, indicating that the low statistical power was not a serious problem. Even so, we will increase the sample sizes and years of follow-up to increase the statistical power to evaluate risk factors in future research.

## Conclusion

We found that different living conditions may have different effects on the health of the elderly. Our results indicate that people who have always lived alone are at high risk of osteoporosis and suggest that such people may need regular bone tests and more care to avoid adverse events.

## Acknowledgements

The authors thank Guiyan Shao from the Chadian Public Health Center and Xiaofang Ren from the Hangu Welfare House for providing data collection sites and mobilizing the participant population.


## Declaration of conflicting interest

The authors declare that there is no conflict of interest.

## Funding

This work was supported by grants from the National Natural Science Foundation of China (81601952), the Tianjin Municipal Science and Technology Commission (16ZXMJSY00070, Tianjin, China), and the Health and Family Planning Commission of Binhai New Area (2017BWKZ005).

## ORCID iD

Qi Guo  <https://orcid.org/0000-0003-0439-8274>

## References

1. Rachner TD, Khosla S and Hofbauer LC. Osteoporosis: now and the future. *Lancet* 2011; 377: 1276–1287.
2. Chen P, Li Z and Hu Y. Prevalence of osteoporosis in China: a meta-analysis and systematic review. *BMC Public Health* 2016; 16: 1039.
3. Nih Consensus Development Panel on Osteoporosis Prevention D, Therapy. Osteoporosis prevention, diagnosis, and therapy. *JAMA* 2001; 285: 785–795.
4. Michael YL, Berkman LF, Colditz GA, et al. Living arrangements, social integration, and change in functional health status. *Am J Epidemiol* 2001; 153: 123–131.
5. Sun X, Lucas H, Meng Q, et al. Associations between living arrangements and health-related quality of life of urban elderly people: a study from China. *Qual Life Res* 2011; 20: 359–369.
6. Kharicha K, Iliffe S, Harari D, et al. Health risk appraisal in older people 1: are older people living alone an “at-risk” group? *Br J Gen Pract* 2007; 57: 271–276.
7. Kim SW, Bae KH, Seo JB, et al. Association between household size, residential area, and osteoporosis: analysis of 2008 to 2011 Korea National Health and Nutrition Examination Survey. *Korean J Intern Med* 2016; 31: 712–721.
8. Kim J, Lee J, Shin JY, et al. Socioeconomic disparities in osteoporosis prevalence: different results in the overall Korean adult population and single-person households. *J Prev Med Public Health* 2015; 48: 84–93.

9. Lehmann SW, Black BS, Shore A, et al. Living alone with dementia: lack of awareness adds to functional and cognitive vulnerabilities. *Int Psychogeriatr* 2010; 22: 778–784.
10. Wang H, Chen K, Pan Y, et al. Associations and impact factors between living arrangements and functional disability among older Chinese adults. *PLoS One* 2013; 8: e53879.
11. Han P, Yu H, Ma Y, et al. The increased risk of sarcopenia in patients with cardiovascular risk factors in Suburb-Dwelling older Chinese using the AWGS definition. *Sci Rep* 2017; 7: 9592.
12. Zhang W, Shen S, Wang W, et al. Poor lower extremity function was associated with pre-diabetes and diabetes in older Chinese people. *PLoS One* 2014; 9: e115883.
13. Smarr KL and Keefer AL. Measures of depression and depressive symptoms: Beck Depression Inventory-II (BDI-II), Center for Epidemiologic Studies Depression Scale (CES-D), Geriatric Depression Scale (GDS), Hospital Anxiety and Depression Scale (HADS), and Patient Health Questionnaire-9 (PHQ-9). *Arthritis Care Res (Hoboken)* 2011; 63: S454–S466.
14. Jiang CQ, Xu L, Lam TH, et al. [Effect of physical activity strength on the diabetes mellitus prevalence in the elderly under the influence of International Physical Activity Questionnaire]. *Zhonghua Liu Xing Bing Xue Za Zhi* 2009; 30: 462–465.
15. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. *Osteoporos Int* 1994; 4: 368–381.
16. Chin KY, Low NY, Dewiputri WI, et al. Factors associated with bone health in Malaysian middle-aged and elderly women assessed via quantitative ultrasound. *Int J Environ Res Public Health* 2017; 14: 736.
17. Vaizura MN, Ima-Nirwana S and Kok-Yong C. A concise review of testosterone and bone health. *Clin Interv Aging* 2016; 11: 1317–1324.
18. Braun SI, Kim Y, Jetton AE, et al. Sedentary behavior, physical activity, and bone health in postmenopausal women. *J Aging Phys Act* 2017; 25: 173–181.
19. Mezuk B, Eaton WW and Golden SH. Depression and osteoporosis: epidemiology and potential mediating pathways. *Osteoporos Int* 2008; 19: 1–12.
20. Troy KL, Mancuso ME, Butler TA, et al. Exercise early and often: effects of physical activity and exercise on women's bone health. *Int J Environ Res Public Health* 2018; 15: 858.
21. Sbarra DA and Nietert PJ. Divorce and death: forty years of the Charleston Heart Study. *Psychol Sci* 2009; 20: 107–113.
22. Liu N, Zeng L, Li Z, et al. Health-related quality of life and long-term care needs among elderly individuals living alone: a cross-sectional study in rural areas of Shaanxi Province, China. *BMC Public Health* 2013; 13: 313.
23. Williams BR, Zhang Y, Sawyer P, et al. Intrinsic association of widowhood with mortality in community-dwelling older women and men: findings from a prospective propensity-matched population study. *J Gerontol A Biol Sci Med Sci* 2011; 66: 1360–1368.
24. Mostofsky E, Maclure M, Sherwood JB, et al. Risk of acute myocardial infarction after the death of a significant person in one's life: the Determinants of Myocardial Infarction Onset Study. *Circulation* 2012; 125: 491–496.
25. Kitamura T, Sakata Y, Nakatani D, et al. Living alone and risk of cardiovascular events following discharge after acute myocardial infarction in Japan. *J Cardiol* 2013; 62: 257–262.
26. Hauser B, Riches PL, Wilson JF, et al. Prevalence and clinical prediction of osteoporosis in a contemporary cohort of patients with rheumatoid arthritis. *Rheumatology (Oxford)* 2014; 53: 1759–1766.
27. Vestergaard P. Discrepancies in bone mineral density and fracture risk in patients with type 1 and type 2 diabetes—a meta-analysis. *Osteoporos Int* 2007; 18: 427–444.
28. Iki M, Fujita Y, Kouda K, et al. Hyperglycemia is associated with increased bone mineral density and decreased trabecular bone score in elderly Japanese men: the Fujiwara-kyo osteoporosis risk in men (FORMEN) study. *Bone* 2017; 105: 18–25.

- 
29. Sun W, Watanabe M, Tanimoto Y, et al. Factors associated with good self-rated health of non-disabled elderly living alone in Japan: a cross-sectional study. *BMC Public Health* 2007; 7: 297.
  30. Kemmler W and Von Stengel S. Exercise and osteoporosis-related fractures: perspectives and recommendations of the sports and exercise scientist. *Phys Sportsmed* 2011; 39: 142–157.
  31. Howe TE, Shea B, Dawson LJ, et al. Exercise for preventing and treating osteoporosis in postmenopausal women. *Cochrane Database Syst Rev* 2011; (7): CD000333. DOI: 10.1002/14651858.CD000333.pub2.