Chapter 12

Falls and Related Bone Fractures

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1 Introduction

According to the 2016 Vital Statistics of Japan, 8030 people die from falling each year, 88% of whom are 65 years and older [1]. The primary cause of functional disability is a bone fracture in 12% of the cases [2], and falls and related bone fractures are a critical public health issue among the elderly population. In this chapter, we first look at the frequency of falls and related bone fractures and the regional differences in their distribution. This is followed by a review of the literature regarding the association between falls and related bone fractures and socioeconomic status (SES), and a discussion of the reasons for the association and possible approaches to preventing falls.

2 Frequency of and Regional Differences in Falls and Related Bone Fractures

Approximately 10–20% of community-dwelling older adults living in Japan fall at least once per year [3–7]. Bone fracture occurs in approximately 10% of falls [8], and it is estimated that slightly fewer than 10% of those are hip fractures [9]. The annual

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rate of falls is 5% among persons aged 65–69 years, and increases with age to 22% among those aged 85 years and older [5]. The relationship between bone fracture and aging is striking, with hip fracture occurring in 7.3 per 10,000 people in their 60s, and occurring more frequently in 271.7 per 10,000 people in their 90s [10].

In terms of geographical occurrence, it may be reasonable to expect that bone fractures would be more frequent in cold regions where road surfaces freeze in the winter. However, contrary to this expectation, an ongoing nationwide survey conducted by Orimo et al. [10, 11] since 1987 has continually shown that the incidence of hip fracture is less frequent in cold regions (Fig. 12.1). In a regional correlation study conducted by Yaegashi et al. [12], a relationship with vitamin K is cited as a reason for this regional difference, and although Kaneki et al. [13] have reported that the large amount of *natto* (fermented soybean) consumed in eastern Japan may correlate to the incidence of bone fracture, the reason for this regional difference is still under debate.

3 Association Between Falls and Related Bone Fractures and SES

In a regional correlation study using a deprivation index calculated from the average income, unemployment rate, and other factors for each region, and in a study using individual income, it has been reported that the incidence of falls and related bone fractures is high among socioeconomically impoverished regions and individuals.

Fig. 12.1 Standardized incidence rate of hip fracture (from Orimo et al. [11]). Note: Calculated from the European standard incidence rate

Below, we introduce the relationships of falls (and related bone fractures) with (1) the regional deprivation index, (2) individual income, (3) education index, and (4) other indices.

$$\text{Standardized incidence ratio} = \frac{B}{\sum(I \times P)}$$

where B is the estimated number of patients by regional block, I is the estimated national incidence rate by gender/age, and P is the estimated regional block population by gender/age.

3.1 Regional Deprivation Index and Falls and Related Bone Fractures

First, considering falls, in a cross-sectional study conducted by Lawlor et al. [14] among 4050 older women aged 60–79 years in Britain, no significant difference in the incidence of falls was seen depending on the level of regional impoverishment or social class. In a study on the relationship between the probability of hospitalization because of injury (including injuries from causes other than falls) and regional impoverishment (at five levels) conducted in Wales by Lyons et al. [15] among 90,935 subjects, hospitalization because of injury tended to be more frequent in more impoverished regions overall, but there was variability in the association depending on the age and cause. Although the rate of hospitalization because of falls among people aged 75 years and older was the lowest in the wealthiest region and the highest in the poorest region, there was a nonlinear association between impoverishment and hospitalization [15].

No significant correlation was found between bone fracture and income in a study conducted in the United States by Gornick et al. [16] in 1996 ($n = 26,253,266$). However, in an analysis of 5167 discharged Caucasian patients aged 50 years and older performed by Bacon and Hadden [17], a negative linear correlation was observed between the regional average income and the rate of hospitalization caused by hip fracture. In a study of 43,806 older people aged 75 years and older in England conducted by West et al. [18], the hospitalization rate caused by all bone fractures was 1.10 times higher (95% confidence interval, 1.01–1.19) in the poorest region than in the wealthiest region, and there was no significant difference considering hip fracture alone. Furthermore, recent reports included a cross-sectional study conducted by Bhimjiyani et al. [19] among 747,369 patients with hip fractures aged 50 years and older in Britain as subjects. While the authors did not find a correlation between regional impoverishment and the incidence rate of falls between the central and southern regions of Britain, they reported a high incidence rate of falls in the poorest parts of the northern region. Regarding the mortality rate associated with hip fractures, an analysis performed by Hsu et al. [20] of 193,158 patients with hip fractures aged 65 years and older as subjects reported that the mortality rate was low 1 year after the onset in regions with the highest household income compared to regions with the lowest household income.

3.2 *Individual Income and Falls and Related Bone Fractures*

Wallace et al. [21] conducted a study on falls by surveying 42,044 older adults aged 65 years and older in California. They found that the annual incidence of falls in 2003 increased with decreasing income, with the incidence rate of the poorest group (18%) being twice as high as that of the wealthiest group (9%).

In a cross-sectional study conducted by Chang and Do [22] among 14,881 community-dwelling older people aged 65 years and older as subjects, the incidence rate of falls was lower among women with household incomes of \$20,000 and above (\$20,000–39,999, \$40,000–59,999, and $\geq$ \$60,000), in comparison to women with household income $<$ \$20,000.

However, no significant association was observed in cross-sectional studies with fewer subjects compared with those studies. A study conducted in Brazil by Siqueira et al. [23], involving a random sample of 6616 older adults aged 60 years and above, revealed that while the incidence rate of falls tended to decrease with increasing income, no significant difference was found among the income groups.

Moreover, no significant correlation between falling and income was observed in the abovementioned study conducted by Lawlor et al. [14], a study of 1709 randomly selected older people aged 65 years and older conducted in the USA by Boyd and Stevens [24], or in a telephone survey of 2619 older people aged 65 years and older conducted in Australia by Gill et al. [25] Among these studies, Gill et al. [25] showed that the rate of falls was high in groups that did not answer questions about income (odds ratio, 1.34; 95% confidence interval, 1.04–1.73), but this is with the caveat that in this situation, the study was on the subject of income, which is difficult to respond to, or study results were being interpreted.

A longitudinal study conducted by Hanlon et al. [26] among 2996 people in the USA revealed no significant association between income and falls.

A prospective cohort study of a random sample of 16,578 people aged 20–74 years in the Netherlands conducted by van Lenthe et al. [27] indicated that the lower the income, the higher was the incidence rate of hip fractures, and that the adjusted hazard ratio was 2.28 times higher in the lowest income group than in the highest income group (95% confidence interval, 1.40–3.73). Similar results were also found in a study conducted by Brennan et al. [28] A case-control study conducted by Hansen et al. [29] with inpatients and outpatients as subjects (case group: 351,379 people, control group: 351,379 people) indicated that there was a low risk of hip fractures, humeral fractures, and wrist fractures in the highest income group when compared with the average income group. Farahmand et al. [30] conducted a case-control study on bone fracture among postmenopausal women in Sweden (case group: 1327, control group: 3262), and found that the rate of hip fracture was significantly lower in individuals with high income (adjusted odds ratio, 0.74; 95% confidence interval, 0.60–0.90). A study conducted by Kristensen et al. [31] with 25,324 patients with hip fractures aged 65 years and older as subjects in Denmark, a study conducted by Quah et al. [32] with 6300 patients aged 65 years and older in Britain, and a study conducted by Leslie et al. [33] among 104,293 community-dwelling

residents aged 50 years and older in Canada all reported that the mortality rate associated with hip fractures was high in the low income group.

The association between regional impoverishment or income and bone fractures is relatively clear, as shown in Table 12.1, but a significant difference has only been seen in large-scale studies on falls with 10,000 or more subjects, suggesting that a large sample size is required to detect an association between impoverishment or income and falls. In addition, a regional correlation study conducted by Jones et al. [41], which analyzed the injury database of Wales, provided important suggestions for interpreting the variability in findings. They compared the bone fracture injury rate of impoverished regions and wealthy regions by age group and found that although the bone fracture injury rate was noticeably high in impoverished regions in the younger strata, the difference was small in the older strata. The difference in bone fracture rate between impoverished regions and wealthy regions was greatest in the 35–44 years age group, at 1.64 times (95% confidence interval, 1.57–1.72), but in the ≥ 85 years age group, it was 0.94 times (95% confidence interval, 0.87–1.01) without a significant difference. Although extrinsic factors are strong and socioeconomic factors have a large influence on bone fracture in middle-aged patients, it is estimated that intrinsic factors are strong in later old age and the influence of socioeconomic factors is small.

3.3 *Level of Education and Falls and Related Bone Fractures*

Some studies have shown that the rate of falls is high among people with a higher level of education, while other studies show the converse; thus, there is still no consensus. Among cross-sectional studies, Boyd and Stevens [24] reported no difference in the incidence rate of falls regardless of whether subjects were high school graduates ($n = 1709$). However, Cevizci et al. [43] reported a difference in the fall rate between subjects who were high school graduates and those who were not ($n = 1001$). Gill et al. [25] reported that the fall rate was lower among 2619 subjects who were university graduates or had achieved higher education (adjusted odds ratio, 0.63; 95% confidence interval, 0.43–0.94). In a review of recent reports, Vieira et al. [36] reported that in a random sample of 1451 people aged ≥ 60 years in Brazil, the adjusted odds ratio for the incidence of falls was higher among people with 4–7 years of education (adjusted odds ratio, 1.40; 95% confidence interval, 1.09–1.80) and uneducated people (adjusted odds ratio, 1.47; 95% confidence interval, 1.09–1.80) in comparison to people with ≥ 12 years of education. In addition, a study of a random sample of 1182 people aged ≥ 60 years in Saudi Arabia by Almegble et al. [37] revealed a higher adjusted odds ratio for the incidence of falls among middle school graduates and uneducated people in comparison to university graduates.

Regarding longitudinal studies, in a 2-year cohort study conducted by Reyes-Ortiz et al. [44] among 3050 older adults of Mexican descent in the United States, there was no significant difference in the rate of falls according to the level of educa-

Table 12.1 Relationship between income and regional impoverishment and falls and related bone fractures

Outcome	Authors	Year of publication	Country	Study type	Subjects	Age (years)	No. of subjects	Primary result regarding income or deprivation index
Falls	Hayashi et al. [34]	2014	Japan	Cross-sectional study	Community-dwelling older persons	>65	90,610	The incidence rate of falls was high in the low-income group compared to the high-income group
	Wallace et al. [21]	2007	USA	Regional correlation study	Regional representative sample	>65	42,044	The lower the income, the higher the incidence rate of falls
	Matsuda et al. [35]	2005	Japan	Cross-sectional study	Community-dwelling older persons	>65	29,131	More frequent history of falling in lower income strata ($P < 0.001$)
	Chang et al. [22]	2015	Canada	Cross-sectional study	Community-dwelling older persons	>65	14,881	The incidence rate for falls was low among the wealthiest and second wealthiest groups in comparison to the lowest income group (only for women)
	Lyons et al. [15]	2003	Britain	Regional correlation study	Data of hospitalized patients	≥75	13,277	In the wealthiest region, the standardized hospitalization rate due to injury was significantly lower, at 0.900, but in the next-wealthiest region, it was the highest, at 1.088

Siqueira et al. [23]	2011	Brazil	Cross-sectional study	Regional representative sample	>60	6616	The higher the income of the group, the lower was the tendency of the incidence rate for falls
Lawlor et al. [14]	2003	Britain	Cross-sectional study	Regional representative sample	60–79	4050	No significant association was observed between regional impoverishment and the incidence rate of falls
Boyd and Stevens [24]	2009	USA	Cross-sectional study	Regional representative sample	>65	1709	No significant association was observed between income and the incidence rate of falls
Hanlon et al. [26]	2002	USA	Prospective cohort study	Community-dwelling older persons	>65	2996	No significant association was observed between income and the incidence rate of falls
Gill et al. [25]	2005	Australia	Cross-sectional study	Community-dwelling older persons	>65	2619	No significant association was observed between income and the incidence rate of falls
Vieira et al. [36]	2018	Brazil	Cross-sectional study	Regional representative sample	>60	1451	The lower the income of the group, the higher was the incidence rate of falls
Almegebel et al. [37]	2018	Saudi Arabia	Cross-sectional study	Regional representative sample	>60	1182	The incidence rate of falls was high among people who rented houses compared to those who owned houses
Yasumura et al. [3]	1994	Japan	Cross-sectional study	Community-dwelling older persons	>65	807	No significant association was observed between income and the incidence rate of falls
Brito et al. [38]	2014	Brazil	Cross-sectional study	Community-dwelling older persons	>60	316	No significant association was observed between income and the incidence rate of falls

(continued)

Table 12.1 (continued)

Outcome	Authors	Year of publication	Country	Study type	Subjects	Age (years)	No. of subjects	Primary result regarding income or deprivation index
Bone fractures	Gornick et al. [16]	1996	USA	Regional correlation study	Medicare beneficiaries	>65	26,253,266	No significant association was observed between income and the hip fracture treatment rate
	Lin et al. [39]	2018	Taiwan	Retrospective cohort study	Regional representative sample	All ages	1,000,000	No significant association was observed between income and the hip fracture incidence rate
	Bhimjiyani et al. [19]	2018	Britain	Continuous cross-sectional study	Hip fracture patients	>50	747,369	The incidence rate of bone fractures was high in the poorest regions (only in north England)
	Hansen et al. [29]	2018	Danish	Case-control study	Inpatients and outpatients	>50	Case group 351,379; control group 351,379	The bone fracture incidence rate was low in the wealthiest income group compared to the average income group
	Hsu et al. [20]	2018	Taiwan	Retrospective cohort study	Patients hospitalized due to hip fracture	>65	193,158	The mortality rate was low 1 year after onset in regions with the highest average household income compared to regions with the lowest average household income
	Brennan et al. [28]	2015	Canada	Retrospective cohort study	Undescribed	>50	Undescribed	The bone fracture incidence rate was high in the poorest income group compared to the wealthiest income group
	Leslie et al. [33]	2013	Canada	Case-control study	Community-dwelling older persons	>50	First Nation peoples = 63,081 Non-First Nation peoples = 41,211	The risk of mortality associated with bone fractures was high in the low-income group compared to the high-income group

Oliveira et al. [40]	2014	Portugal	Regional correlation study	Discharged hip fracture patients	>50	96,905	The bone fracture rate was low for women in wealthy regions compared to women in poor regions
Jones et al. [41]	2004	Britain	Regional correlation study	Bone fracture patients	All ages	60,106	In younger strata, the bone fracture rate was particularly high in impoverished regions, and the difference decreased with increasing age
Brennan et al. [42]	2014	Canada	Retrospective cohort study	Community- dwelling older persons	>50 (females)	51,327	The incidence rate of osteoporosis and falls were high for the poorest income group compared to the wealthiest income group
West et al. [18]	2004	Britain	Regional correlation study	Patients hospitalized due to fall or bone fracture	>75	43,806	In low-income regions, the hospitalization rate due to bone fracture was 1.1 times higher
Kristensen et al. [31]	2016	Danish	Prospective cohort study	Patients hospitalized due to hip fracture	>65	25,354	The mortality rate within 30 days after injury was low in the high-income group compared to the low-income group

(continued)

Table 12.1 (continued)

Outcome	Authors	Year of publication	Country	Study type	Subjects	Age (years)	No. of subjects	Primary result regarding income or deprivation index
	van Lenthe et al. [27]	2011	Netherlands	Prospective cohort study	Regional representative sample	20–74	16,578	The incidence rates of falls were high in the low- and middle-income groups compared to the high-income group
	Quah et al. [32]	2011	Britain	Prospective cohort study	Patients hospitalized due to hip fracture	>65	6300	The poorest group had a high bone fracture incidence rate and mortality rate compared to the wealthiest group
	Bacon et al. [17]	2000	USA	Regional correlation study	Discharged hip fracture patients	>50	5167	Negative correlation between the hip fracture incidence rate and income
	Farahmand et al. [30]	2000	Sweden	Case-control study	Postmenopausal female hip fracture patients	50–81 (females)	Case group 1327; control group 3262	The hip fracture incidence rate was significantly lower with higher income (odds ratio 0.74)

“Community-dwelling elderly persons” excludes institutional residents; “Regional representative sample” indicates a study in which a sample was extracted from a resident database.

tion. However, in a study conducted by Hanlon et al. [26] ($n = 2996$), the group with ≥ 13 years of education showed a 1.49 higher adjusted odds ratio for the incidence rate of falls compared with the group with ≤ 8 years of education (95% confidence interval, 1.05–2.12). Ryu et al. [45] ($n = 12,286$) also reported a 1.29 times higher adjusted odds ratio for people with high school or less compared with university graduates or those that had achieved higher education (95% confidence interval, 1.00–1.66).

In a study conducted by Woo et al. [46] in Hong Kong that followed 3890 people for 2 years, the incidence rate for falls was 1.77 times higher (95% confidence interval, 1.09–2.88) among female university graduates than among women with an elementary school education, but no significance was observed in multiple logistic regression analysis. Similarly, in a study conducted in Hong Kong by Chu et al. [47] that followed 1517 people for 1 year, there was no significant difference in the fall rate depending on the level of education. In a longitudinal study of 335 Koreans aged ≥ 60 years, there was also no significant association between falls and the level of education [48]. In a longitudinal aging study conducted in Amsterdam, among 1365 community-dwelling older persons who had fallen, those who had repeatedly fallen two or more times in 6 months had significantly higher levels of education than those who had not ($p = 0.020$) [49]. Among persons with ≥ 11 years of education, the recurrence rate of falls was significantly higher (univariate analysis odds ratio, 1.36; 95% confidence interval, 1.04–1.77), and Cox proportional hazards analysis with respect to the total number of bone fractures in 6 years demonstrated that whether a person had ≥ 11 years of education was not a significant variable [50]. Regarding the mortality rate after falls, a prospective cohort study with 566,478 community-dwelling older people aged 50–75 years in Sweden as subjects reported an adjusted hazard ratio of 1.4 for mortality among men with less than 10–12 years of education (95% confidence interval, 1.1–1.8), and 1.8 (95% confidence interval, 1.4–2.3) among men with less than 0–9 years of education compared to men with ≥ 12 years of education. Thus, the mortality rate was higher after falls among the group of men with poor education [51].

The above review indicates that for cross-sectional studies, there has been a recent increase in reports of a low incidence rate of falls among subjects with increasing level of education. However, longitudinal studies have not reached a consensus to date.

3.4 Other Indices

Regarding community correlation studies, a study conducted by Gribbin et al. [52] that followed 61,248 persons aged ≥ 60 years in Britain reported an increase in the fall rate with decreasing SES of the community, as calculated from census data for occupation and private automobile ownership ($p < 0.0001$). In a study conducted by

Turner et al. [53] among 5250 hospitalized older Australians, the subjects were divided into five strata of SES by region graded according to income, unemployment rate, and education level, and the association with hospitalization rate caused by hip fracture was assessed. Compared with the region with the lowest SES, the regions with the second and third lowest SES had significantly lower standardized hospitalization rates, at 0.837 (95% confidence interval, 0.717–0.972) and 0.855 (95% confidence interval, 0.743–0.989), respectively. In a report from the USA by Wallace et al. [21], there were differences in the fall rate depending on race, with a rate of 12% among both Caucasians and African-Americans; a high rate of 19% and 17% among Native Americans and the indigenous people of Alaska, respectively; and a low rate of 8% among Asians and Pacific Islanders.

In the Swedish case-control study conducted by Farahmand et al. [30] (case group 1327, control group 3262), the rate of hip fracture injury was significantly lower among employed persons (adjusted odds ratio, 0.74; 95% confidence interval, 0.56–0.96) and homeowners (adjusted odds ratio, 0.85; 95% confidence interval, 0.72–0.99). In the cross-sectional study conducted in Australia by Gill et al. [25] ($n = 2619$), the fall rate was significantly higher among persons living alone (adjusted odds ratio, 1.45; 95% confidence interval, 1.22–1.73).

In a longitudinal study conducted by Chu et al. [47] in Hong Kong ($n = 1517$), there was no significant difference in the fall rate depending on whether a person was employed. However, in a cross-sectional study conducted by Ho et al. [54] in Hong Kong among 1947 subjects aged ≥ 70 years, the fall rate was significantly lower among those who used to be blue-collar workers than among those who used to be white-collar workers (odds ratio, 0.8; 95% confidence interval, 0.6–0.9).

In summary, although it has been reported that the fall rate is high among people living alone, people who do not own homes, unemployed people, and people living in a region of low SES, some authors have also reported a higher fall rate for white-collar workers than for blue-collar workers, indicating a lack of consensus.

3.5 Findings in Japan

Although few studies on falls and fractures in Japan have investigated the correlation with SES, a number of interesting studies have been conducted. A study of 807 people in Japan conducted by Yasumura et al. [3] showed that there was no significant correlation between falling and SES (income/education). However, studies using large-scale data reported a correlation between income, education, and falling incidence. In the Aichi Gerontological Evaluation Study, which surveyed 29,131 community-dwelling older people, when divided into groups of equivalent income of <2 million yen, 2–4 million yen, and >4 million yen, Matsuda et al. [35] reported a higher rate of falls among both men and women (all $p < 0.001$) with decreasing income. When the subjects were divided into those with <6 years, 6–9 years,

10–12 years, and ≥ 13 years of education, the adjusted fall rate was significantly higher among women with fewer years of education ($p < 0.001$). A study conducted by Hayashi et al. [34] with 90,610 older adults aged ≥ 65 years in 31 cities, towns, and villages in Japan as subjects divided the subjects according to three levels of income (<1.5 million yen, 1.5–2.5 million yen, and ≥ 2.5 million yen). The authors reported that while the adjusted odds ratio was high for fall incidence among subjects with an income of <1.5 million yen, this significant correlation disappeared after the addition of variables of regional environment (neighborhood built environment and population density) and adjustment. Similarly, an ecological study conducted by Hayashi et al. [55] discussed the incidence rate of falls and its related factors between regions among 16,102 subjects from nine cities and towns and 64 elementary school districts. This study identified the regions with fewer falls (elementary school district with the fewest falls: 7.4%, elementary school district with the most falls: 31.1%), and indicated a higher incidence rate of falls among low-income earners ($r_s = -0.54$, $p < 0.01$) and poorly educated people ($r_s = -0.41$, $p < 0.01$) in the regions. Furthermore, this study indicated a higher participation rate in regional sports groups (indicative of a form of social participation) with a lower incidence rate of falls in the regions after adjusting for SES. The study indicated a correlation between the regional incidence rate of falls and social participation [55]. In terms of the regional disparity in the incidence rate of falls, a study conducted by Yamada et al. [56], which had 8943 people from seven cities and towns as subjects, reported a significant disparity in the incidence rate of falls among cities, towns, and villages (range, 8.0–10.1%), even after adjustment for individual-level and environmental factors correlated to falls.

4 Reasons for the Influence of SES on Falls and Related Bone Fractures

As described above, although some findings lack consistency, in studies that used a large sample size and standard variables, it was observed that the strata of lower SES tend to have a higher incidence of falls and bone fractures. If this is true, we may be able to explain the path of influence.

Factors that affect the occurrence of falls include intrinsic factors such as reduced sensation, muscular strength, and balance, as well as extrinsic factors such as the living environment and the effects of medication. As shown in the guidelines of the American Geriatrics Society [57] and a systematic review performed by Moreland et al. [58], in addition to low muscular strength and visual impairment, depression, cerebrovascular disorder, dementia, and use of multiple medications are strong risk factors for falls, but several of these are known to be associated with SES (Table 12.2).

Low muscular strength, particularly of the legs, is strongly associated with falls [59]. Muscular strength correlates with the amount of physical activity, but

Table 12.2 Risk factors of falls

	Number of studies indicating significant difference/total number of studies ^a	Mean relative risk ^b (or mean odds ratio)	95% confidence interval
Low muscular strength	10/11	4.4	1.5–10.3
History of a fall	12/13	3.0	1.7–7.0
Walking disability	10/12	2.9	1.3–5.6
Balance disability	8/11	2.9	1.6–5.4
Use of walking assistance device	8/8	2.6	1.2–4.6
Visual impairment	6/12	2.5	1.6–3.5
Arthritis	3/7	2.4	1.9–2.9
ADL disability	8/9	2.3	1.5–3.1
Depression	3/6	2.2	1.7–2.5
Cognitive impairment	4/11	1.8	1.0–2.3
Age >80 years	5/8	1.7	1.1–2.5

Data from American Geriatrics Society British Geriatrics Society and American Academy of Orthopaedic Surgeons Panel on Falls Prevention [57]

ADL activity of daily living

^aNumber of studies in which a significant relative risk or odds ratio was indicated in the univariate analysis

^bRelative risk was calculated from a prospective survey; odds ratio was calculated from a retrospective survey

in a Canadian study on income and amount of physical activity, habitually active people accounted for 12.6% of the low-income strata and 17.9% of the high-income strata, whereas inactive people made up a greater proportion of the low-income strata at 67.4% compared with the high-income strata at 56.1% [60]. In an analysis of the Aichi Gerontological Evaluation Study data, Murata et al. [61] reported that low-income subjects often had a visual impairment and were affected by disease, and people who walked for less than 30 min/day and did not participate in sports were often in the low-income strata. del Rio Barquero et al. [62] compared bone density between central Barcelona and the suburban regions of low SES, and made the interesting observation that bone density was better maintained in the city center than in the suburbs among both men and women.

A Brazilian study observed that visual impairment often occurs when income and education level are low [63–65], but the frequency of cataract surgery is also lower when the education level is low [66].

Chou and Chi [65], Chiriboga et al. [67], Perrino et al. [68], Murata et al. [69] in the Aichi Gerontological Evaluation Study, and Yoshii et al. [70] reported that depression is closely associated with SES and that lack of social support, low level of education, and low SES indicated by low income are risk factors for depression. In a review performed by Darowski et al. [71], antidepressants were a risk factor

that increased the rate of falls and related bone fractures. It is also known that sleep-inducing drugs, which can lead to falls, are often taken by people of low SES [72]. Moreover, low SES as indicated by lower income is associated with a poor living environment and barriers to healthcare services, which might, in turn, affect health status and increase the risk of falls [73].

We believe that SES affects these risk factors of falls and related bone fractures in a multifaceted and complex manner.

5 Measures Against Falls and Related Bone Fractures that Consider Their Association with SES

Measures against falls and related bone fractures are one of the six key topics of preventive care, and classes on fall prevention are given in various places. However, studies that prove the effect of bone fracture prevention are extremely limited [74], and a significant effect has not been adequately demonstrated by meta-analysis [40, 75, 76]. Falling and related bone fracture prevention projects must always be accompanied by an evaluation of their results. In light of the information provided thus far, we discuss measures that should be taken, in consideration of the association of falls and related bone fractures with SES.

The first measure is an approach that enables high-risk persons to participate in fall-prevention programs. It has been shown that the number of people who do not participate in health checkups to screen for subjects for preventive care programs and the number of people who do not respond to mail surveys are high in low-income groups [77, 78], and that few high-risk people of low SES participate in preventive care programs. In a study conducted by Vind et al. [79], it was shown that the incidence of falls was greater among nonparticipants of a fall-prevention program than among participants. First off, an approach that provides information on the need for prevention to high-risk persons of low SES and urges them to participate in fall-prevention programs is required.

Second, the development of an integral fall and related bone fracture prevention program should be considered. Fall and bone fracture prevention in the past often consisted of a simple intervention program such as muscle-strengthening training, but it is important to provide a multifaceted intervention program that is also relevant to SES, such as maintaining activity, addressing visual impairment, assisting with depression, appropriate use of medications, and maintaining a living environment. This was demonstrated by Chang et al. [80], who, through meta-analysis, found that an integrated program rather than simple exercise reduced the risk of falls (adjusted odds ratio, 0.82; 95% confidence interval, 0.72–0.99). The more socioeconomically disadvantaged people are, the more risk factors they have, and an integrated program may be more effective for persons in the lower socioeconomic strata.

Third, the importance of social participation to promote personal connections and social support should be emphasized. This is particularly important because many socioeconomically disadvantaged people do not leave the house often and interact little with others, thus receiving little social support [81, 82]. Therefore, it is possible that physical activity decreases and the fall risk increases. The aforementioned study conducted by Hayashi et al. [55] indicated a regional difference in the incidence rate of falls and its correlation with SES. However, it was also reported that the lower the regional incidence rate of falls, the higher the participation rate was for regional sports groups, indicative of a form of social participation. In addition, another report of a cross-sectional study indicated a significantly low fall incidence among people who participated once or more a week in sports groups in comparison to those who did not participate. This suggested the possibility that falls could be prevented if individuals exercised [83]. Participation in sports groups was also reported to be effective in not only preventing falls, but also preventing depression and certification of the need for long-term care [84]. Therefore, it is possible that an approach that promotes social participation, such as participation in regional sports groups, can prevent falls through a population strategy with the entire regional population as subjects. The effectiveness of this approach is also anticipated among people of low SES. To proceed with such an approach, support will be required from not only community-dwelling residents participating in such groups, but also local government bodies and experts.

Finally, there is a need for large-scale longitudinal studies. As seen in the above discussion, low SES seems to exert an adverse effect on falls and related bone fractures, but nearly all of those studies were conducted outside Japan, and the validity of their findings must be verified in Japan. Unfortunately, however, there is still little research that longitudinally examines the association between health and SES in Japan. The main point examined in most of the foreign studies discussed in this chapter was not falls and related bone fractures, and the analyses were performed using data from large-scale studies of community-dwelling residents or patients. A system for evaluating the effect of preventive care and health promotion programs over time, including falls and related bone fractures, must be promptly created in Japan.

6 Summary

Poverty increases the incidence of bone fractures, and this association is especially strong in middle age. Because falls and related bone fractures are a primary reason for older adults requiring care and sometimes lead to life-and-death situations, measures must be taken. There is still little medical basis for the effect of prevention measures for falls and related bone fractures, and assessment studies must be conducted in parallel with prevention activities. In light of the association with SES, there is an urgent need for implementation and management of a large-scale longi-

tudinal study that can appropriately evaluate the effectiveness of prevention activities and can be used as feedback while effective integrated prevention programs are developed and community assistance systems are put in place.

References

1. Ministry of Health, Labour and Welfare. 2016 Vital statistics of Japan. Available at https://www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei16/dl/11_h7.pdf.
2. Ministry of Health, Labour and Welfare. 2016 National livelihood survey. Available at <https://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa16/dl/05.pdf>.
3. Yasumura S, Haga H, Nagai H, et al. Rate of falls and the correlates among elderly people living in an urban community in Japan. *Age Ageing*. 1994;23:323–7.
4. Yasumura S, Haga H, Niino N. Circumstances of injurious falls leading to medical care among elderly people living in a rural community. *Arch Gerontol Geriatr*. 1996;23:95–109.
5. Aoyagi K, Ross PD, Davis JW, et al. Falls among community-dwelling elderly in Japan. *J Bone Miner Res*. 1998;13:1468–74.
6. Niino N, Tsuzuku S, Ando F, et al. Frequencies and circumstances of falls in the National Institute for Longevity Sciences, Longitudinal Study of Aging (NILS-LSA). *J Epidemiol*. 2000;10:S90–4.
7. Kitayuguchi J, Kamada M, Okada S, et al. Association between musculoskeletal pain and trips or falls in rural Japanese community-dwelling older adults: a cross-sectional study. *Geriatr Gerontol Int*. 2015;15:54–64.
8. Cabinet Office, Government of Japan. 2005 Survey of housing and activities of the elderly. Available at https://www8.cao.go.jp/kourei/ishiki/h17_sougou/pdf/gaiyou.pdf.
9. Yasumura S. Frequency of falls and related bone fractures in the elderly. *J Jpn Med Assoc*. 1999;122:1945–9. (In Japanese)
10. Orimo H, Sakata K. Results of fourth nationwide hip fracture frequency survey: hip fracture incidence in Japan: estimates of new patients in 2002 and 15-year trends. *Jpn Med J*. 2004;4180:25–30. (In Japanese)
11. Orimo H, Yaegashi Y, Onoda T, et al. Hip fracture incidence in Japan: estimates of new patients in 2007 and 20-year trends. *Arch Osteopor*. 2009;4:71–7.
12. Yaegashi Y, Onoda T, Tanno K, et al. Association of hip fracture incidence and intake of calcium, magnesium, vitamin D, and vitamin K. *Eur J Epidemiol*. 2008;23:219–25.
13. Kaneki M, Hodges SJ, Hosoi T, et al. Japanese fermented soybean food as the major determinant of the large geographic difference in circulating levels of vitamin K2: possible implications for hip-fracture risk. *Nutrition*. 2001;17:315–21.
14. Lawlor DA, Patel R, Ebrahim S. Association between falls in elderly women and chronic diseases and drug use: cross sectional study. *BMJ*. 2003;327:712–7.
15. Lyons RA, Jones SJ, Deacon T, et al. Socioeconomic variation in injury in children and older people: a population based study. *Inj Prev*. 2003;9:33–7.
16. Gornick ME, Eggers PW, Reilly TW, et al. Effects of race and income on mortality and use of services among Medicare beneficiaries. *N Engl J Med*. 1996;335:791–9.
17. Bacon WE, Hadden WC. Occurrence of hip fractures and socioeconomic position. *J Aging Health*. 2000;12:193–203.
18. West J, Hippisley-Cox J, Coupland CA, et al. Do rates of hospital admission for falls and hip fracture in elderly people vary by socio-economic status? *Public Health*. 2004;118:576–81.
19. Bhimjiyani A, Neuburger J, Jones T, et al. Inequalities in hip fracture incidence are greatest in the North of England: regional analysis of the effects of social deprivation on hip fracture incidence across England. *Public Health*. 2018;162:25–31.

20. Hsu IL, Chang CM, Yang DC, et al. Socioeconomic inequality in one-year mortality of elderly people with hip fracture in Taiwan. *Int J Environ Res Public Health*. 2018;15
21. Wallace SP, Molina LC, Jhawar M. Falls, disability and food insecurity present challenges to healthy aging. *Policy Brief UCLA Cent Health Policy Res*. 2007;1–12.
22. Chang VC, Do MT. Risk factors for falls among seniors: implications of gender. *Am J Epidemiol*. 2015;181:521–31.
23. Siqueira FV, Facchini LA, Silveira DS, et al. Prevalence of falls in elderly in Brazil: a country-wide analysis. *Cad Saude Publica*. 2011;27:1819–26.
24. Boyd R, Stevens JA. Falls and fear of falling: burden, beliefs and behaviours. *Age Ageing*. 2009;38:423–8.
25. Gill T, Taylor AW, Pengelly A. A population-based survey of factors relating to the prevalence of falls in older people. *Gerontology*. 2005;51:340–5.
26. Hanlon JT, Landerman LR, Fillenbaum GG, et al. Falls in African American and white community-dwelling elderly residents. *J Gerontol A Biol Sci Med Sci*. 2002;57:M473–8.
27. van Lenthe FJ, Avendano M, van Beeck EF, et al. Childhood and adulthood socioeconomic position and the hospital-based incidence of hip fractures after 13 years of follow-up: the role of health behaviours. *J Epidemiol Community Health*. 2011;65:980–5.
28. Brennan SL, Yan L, Lix LM, et al. Sex- and age-specific associations between income and incident major osteoporotic fractures in Canadian men and women: a population-based analysis. *Osteoporos Int*. 2015;26:59–65.
29. Hansen L, Judge A, Javaid MK, et al. Social inequality and fractures-secular trends in the Danish population: a case-control study. *Osteoporos Int*. 2018;29:2243–50.
30. Farahmand BY, Persson PG, Michaelsson K, et al. Socioeconomic status, marital status and hip fracture risk: a population-based case-control study. *Osteoporos Int*. 2000;11:803–8.
31. Kristensen PK, Thillemann TM, Pedersen AB, et al. Socioeconomic inequality in clinical outcome among hip fracture patients: a nationwide cohort study. *Osteoporos Int*. 2017;28:1233–43.
32. Quah C, Boulton C, Moran C. The influence of socioeconomic status on the incidence, outcome and mortality of fractures of the hip. *J Bone Joint Surg*. 2011;93:801–5.
33. Leslie WD, Brennan SL, Prior HJ, et al. The contributions of First Nations ethnicity, income, and delays in surgery on mortality post-fracture: a population-based analysis. *Osteoporos Int*. 2013;24:1247–56.
34. Hayashi T, Kondo K, Suzuki K, et al. Factors associated with falls in community-dwelling older people with focus on participation in sport organizations: the Japan gerontological evaluation study project. *Biomed Res Int*. 2014;2014:537614.
35. Matsuda R, Hirai H, Kondo K, et al. Large-scale epidemiological survey on preventive care in Japanese elderly (3) health behavior and falling history – correlation with socioeconomic status. *Koshu-Eisei*. 2005;69:231–5. (In Japanese)
36. Vieira LS, Gomes AP, Bierhals IO, et al. Falls among older adults in the South of Brazil: prevalence and determinants. *Rev Saude Publica*. 2018;52:22.
37. Almegbel FY, Alotaibi IM, Alhusain FA, et al. Period prevalence, risk factors and consequent injuries of falling among the Saudi elderly living in Riyadh, Saudi Arabia: a cross-sectional study. *BMJ Open*. 2018;8:e019063.
38. Brito TA, Coqueiro Rda S, Fernandes MH, et al. Determinants of falls in community-dwelling elderly: hierarchical analysis. *Public Health Nurs*. 2014;31:290–7.
39. Lin KB, Yang NP, Lee YH, et al. The incidence and factors of hip fractures and subsequent morbidity in Taiwan: an 11-year population-based cohort study. *PLoS One*. 2018;13:e0192388.
40. Oliver D, Connelly JB, Victor CR, et al. Strategies to prevent falls and fractures in hospitals and care homes and effect of cognitive impairment: systematic review and meta-analyses. *BMJ*. 2007;334:82.
41. Jones S, Johansen A, Brennan J, et al. The effect of socioeconomic deprivation on fracture incidence in the United Kingdom. *Osteoporos Int*. 2004;15:520–4.
42. Brennan SL, Leslie WD, Lix LM, et al. FRAX provides robust fracture prediction regardless of socioeconomic status. *Osteoporos Int*. 2014;25:61–9.

43. Cevizci S, Uluocak S, Aslan C, et al. Prevalence of falls and associated risk factors among aged population: community based cross-sectional study from Turkey. *Cent Eur J Public Health*. 2015;23:233–9.
44. Reyes-Ortiz CA, Al Snih S, Loera J, et al. Risk factors for falling in older Mexican Americans. *Ethn Dis*. 2004;14:417–22.
45. Ryu E, Juhn YJ, Wheeler PH, et al. Individual housing-based socioeconomic status predicts risk of accidental falls among adults. *Ann Epidemiol*. 2017;27:415–20.e2.
46. Woo J, Leung J, Wong S, et al. Development of a simple scoring tool in the primary care setting for prediction of recurrent falls in men and women aged 65 years and over living in the community. *J Clin Nurs*. 2009;18:1038–48.
47. Chu LW, Chi I, Chiu AY. Incidence and predictors of falls in the Chinese elderly. *Ann Acad Med Singapore*. 2005;34:60–72.
48. Shin KR, Kang Y, Hwang EH, et al. The prevalence, characteristics and correlates of falls in Korean community-dwelling older adults. *Int Nurs Rev*. 2009;56:387–92.
49. Stel VS, Pluijm SM, Deeg DJ, et al. A classification tree for predicting recurrent falling in community-dwelling older persons. *J Am Geriatr Soc*. 2003;51:1356–64.
50. Pluijm SM, Smit JH, Tromp EA, et al. A risk profile for identifying community-dwelling elderly with a high risk of recurrent falling: results of a 3-year prospective study. *Osteoporos Int*. 2006;17:417–25.
51. Ahmad Kiadaliri A, Turkiewicz A, Englund M. Educational inequalities in falls mortality among older adults: population-based multiple cause of death data from Sweden. *J Epidemiol Community Health*. 2018;72:68–70.
52. Gribbin J, Hubbard R, Smith C, et al. Incidence and mortality of falls amongst older people in primary care in the United Kingdom. *QJM*. 2009;102:477–83.
53. Turner RM, Hayen A, Dunsmuir WT, et al. Spatial temporal modeling of hospitalizations for fall-related hip fractures in older people. *Osteoporos Int*. 2009;20:1479–85.
54. Ho SC, Woo J, Chan SS, et al. Risk factors for falls in the Chinese elderly population. *J Gerontol A Biol Sci Med Sci*. 1996;51:M195–8.
55. Hayashi T, Kondo K, Yamada M, et al. Does a region with few people who fall – considerations of regional gaps and related factor: JAGES project. *J Health Welf Stat*. 2014;61:1–7. (In Japanese)
56. Yamada M, Matsumoto D, Hayashi T, et al. Does a city with few people who fall: AGES project. *J Health Welf Stat*. 2012;59:1–7. (In Japanese)
57. American Geriatrics Society British Geriatrics Society and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. Guideline for the prevention of falls in older persons. *J Am Geriatr Soc*. 2001;49:664–72.
58. Moreland J, Richardson J, Chan D, et al. Evidence-based guidelines for the secondary prevention of falls in older adults. *Gerontology*. 2003;49:93–116.
59. Moreland JD, Richardson JA, Goldsmith CH, et al. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc*. 2004;52:1121–9.
60. Tang M, Chen Y, Krewski D. Gender-related differences in the association between socioeconomic status and self-reported diabetes. *Int J Epidemiol*. 2003;32:381–5.
61. Murata C, Yamada T, Chen CC, et al. Barriers to health care among the elderly in Japan. *Int J Environ Res Public Health*. 2010;7:1330–41.
62. del Rio Barquero L, Romera Baures M, Pavia Segura J, et al. Bone mineral density in two different socio-economic population groups. *Bone Miner*. 1992;18:159–68.
63. Jack CI, Smith T, Neoh C, et al. Prevalence of low vision in elderly patients admitted to an acute geriatric unit in Liverpool: elderly people who fall are more likely to have low vision. *Gerontology*. 1995;41:280–5.
64. Chong EW, Lamoureux EL, Jenkins MA, et al. Sociodemographic, lifestyle, and medical risk factors for visual impairment in an urban Asian population: the Singapore Malay eye study. *Arch Ophthalmol*. 2009;127:1640–7.

65. Chou KL, Chi I. Financial strain and depressive symptoms in Hong Kong elderly Chinese: the moderating or mediating effect of sense of control. *Aging Ment Health*. 2001;5:23–30.
66. Salomao SR, Soares FS, Berezovsky A, et al. Prevalence and outcomes of cataract surgery in Brazil: the Sao Paulo eye study. *Am J Ophthalmol*. 2009;148:199–206.e2.
67. Chiriboga DA, Black SA, Aranda M, et al. Stress and depressive symptoms among Mexican American elders. *J Gerontol B Psychol Sci Soc Sci*. 2002;57:P559–68.
68. Perrino T, Brown SC, Mason CA, et al. Depressive symptoms among Urban Hispanic older adults in Miami: prevalence and sociodemographic correlates. *Clin Gerontol*. 2009;32:26–43.
69. Murata C, Kondo K, Hirai H, et al. Association between depression and socio-economic status among community-dwelling elderly in Japan: the Aichi Gerontological Evaluation Study (AGES). *Health Place*. 2008;14:406–14.
70. Yoshii K, Kondo K, Hirai H, et al. Large-scale epidemiological survey on preventive care in Japanese elderly (2) socioeconomic differences and regional differences in physical and mental health of the elderly. *Koshu-Eisei*. 2005;69:145–8. (In Japanese)
71. Darowski A, Chambers SA, Chambers DJ. Antidepressants and falls in the elderly. *Drugs Aging*. 2009;26:381–94.
72. Blennow G, Romelsjo A, Leifman H, et al. Sedatives and hypnotics in Stockholm: social factors and kinds of use. *Am J Public Health*. 1994;84:242–6.
73. World Health Organization. WHO global report on falls prevention in older age. Geneva: World Health Organization; 2007.
74. Japan Public Health Association. Report on comprehensive survey project of preventive care. Tokyo: Japan Public Health Association; 2010. (In Japanese)
75. Gillespie LD, Gillespie WJ, Robertson MC, et al. Interventions for preventing falls in elderly people. *Cochrane Database Syst Rev*. 2003;(4):Cd000340.
76. Gates S, Fisher JD, Cooke MW, et al. Multifactorial assessment and targeted intervention for preventing falls and injuries among older people in community and emergency care settings: systematic review and meta-analysis. *BMJ*. 2008;336:130–3.
77. Hiramatsu M, Kondo K, Hirai H. Background factors related to preventive care subjects not getting checkups. *J Health Welf Stat*. 2009;56:1–8. (In Japanese)
78. Suemori K. Trends in non-response. In: Kondo K, editor. Review “Health Gap Society” large-scale epidemiological survey on preventive care in Japanese elderly. Tokyo: Igaku Shoin; 2007. p. 124. (In Japanese)
79. Vind AB, Andersen HE, Pedersen KD, et al. Baseline and follow-up characteristics of participants and nonparticipants in a randomized clinical trial of multifactorial fall prevention in Denmark. *J Am Geriatr Soc*. 2009;57:1844–9.
80. Chang JT, Morton SC, Rubenstein LZ, et al. Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomised clinical trials. *BMJ*. 2004;328:680.
81. Hirai H, Kondo K, Ichida Y, et al. Large-scale epidemiological survey on preventive care in Japanese elderly (6) “Homeboundness” among the elderly. *Koshu-Eisei*. 2005;69:485–9. (In Japanese)
82. Saito Y, Kondo K, Yoshii K, et al. Large-scale epidemiological survey on preventive care in Japanese elderly (8) health and social support of the elderly: accepted support and provided support. *Koshu-Eisei*. 2005;69:661–5. (In Japanese)
83. Hayashi T, Kondo K, Kanamori S, et al. Differences in falls between older adult participants in group exercise and those who exercise alone: a cross-sectional study using Japan Gerontological Evaluation Study (JAGES) data. *Int J Environ Res Public Health*. 2018;15:1413.
84. Kanamori S, Kai Y, Kondo K, et al. Participation in sports organizations and the prevention of functional disability in older Japanese: the AGES Cohort Study. *PLoS One*. 2012;7:e51061.

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