Original article

The association of kyphosis assessed in supine and standing positions with future activities of daily living dependence: The Kurabuchi Study

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Abstract

Introduction We have previously found an association between severe kyphosis and future dependence in activities of daily living (ADL) in people who manifest the condition in the supine position (structural curvature). However, because some people show severe kyphosis only in the standing position (postural curvature), we combined our noninvasively obtained kyphosis measurements from participants in the supine position (block method) with those obtained from participants in the standing position (kyphosis index) to determine whether not only structural curvature but also postural curvature is associated with ADL dependence and death.

Methods Between 2005 and 2006, we carried out health evaluations of adults aged 65 years or older in Kurabuchi Town, Japan: 792 participants (337 males, 455 females) who were independent in ADL at baseline and underwent evaluation of kyphotic posture were followed up until March 2014 (mean follow-up: 7.5 years). Participants who experienced one or more admissions to a nursing home, certification of a need for long-term care/support, or a decline in the Katz ADL Index during the follow-up period were defined as being dependent in ADL.

Results A flat back (straight spine in a standing position) and structural curvature were associated with future ADL dependence, but postural curvature was not. The multivariate-adjusted odds ratios (95% confidence interval) compared with physiological curvature (physiological curvature in a standing position) as the reference were 1.72 (1.04-2.86) for a flat back and 2.76 (1.59-4.79) for structural curvature. A weak association with death was observed in those with structural curvature.

Conclusions Our results suggest that the prognoses of people with kyphosis differ according to the type of kyphotic posture.

Keywords Kyphotic posture type, Block method, Kyphosis index, Cohort

Mini abstract We investigated the longitudinal association of noninvasively evaluated kyphotic posture with future dependence in activities of daily living and death in a community-dwelling older Japanese. We found that the association with outcomes varied according to the types of kyphotic posture.

Introduction

In the current aging society, extending healthy life expectancy is more important than simply extending life expectancy itself, and studies on how elderly people can maintain independence in activities of daily living (ADL) are essential in addressing this issue. In the Global Burden of Disease Study 2013, motor organ impairment, such as low back pain, ranked first, followed by neck pain, osteoarthrosis, and other musculoskeletal diseases in determining the number of years lived with disability [1]. However, knowledge about the effects of motor organ impairment on life expectancy, and especially epidemiological evidence, is lacking in comparison with data on cancer and circulatory diseases.

Posture-associated spinal health disorders in the elderly are increasingly being examined, and several studies have evaluated reductions in quality of life (QOL) [2], chronic back pain [3], gait disorder [4], and decreased subjective health and life satisfaction [5] resulting from abnormal sagittal balance due to increased kyphotic posture [6]. However, there is a little epidemiological evidence of the influence of kyphotic posture on dependence in ADL and death in elderly people [7-10].

We previously reported that kyphosis as measured with the block method [7] was associated with future dependence in ADL [11]. The block method measures posture in the supine position; it is suitable for evaluating kyphotic posture as expressed by the bony elements alone, and for detecting kyphosis that is caused mainly by compression fractures accompanying osteoporosis. We referred to this kind of kyphosis as structural curvature. However, we found that some participants did not show severe kyphosis when assessed with the block method, while they did show severe kyphosis in the standing position. Severe kyphosis detected in the standing position but not in the supine position seems likely to be linked with muscle weakness without any obvious compression fractures. We referred to this kind of kyphosis as postural curvature and speculated that it might also be a risk factor for ADL dependence, because severe kyphosis assessed in the standing position is inversely associated with trunk lean mass [12] as a surrogate marker of muscle strength in relation to ADL in older adults [13]. To investigate the effects of postural curvature kyphosis on prognosis, therefore, we combined kyphosis measurements taken when participants were in the supine position with those made when they were in the standing position, and this enabled us to divide kyphotic posture into several types.

In this study, we explored the association of noninvasively evaluated kyphotic posture with future dependence in ADL and death in a community-dwelling older population. Our hypothesis was that not only structural curvature kyphosis but also postural curvature kyphosis was a risk factor for morbidity and mortality.

Methods

Study population

The participants were community-dwelling elderly adults aged 65 years or older in Kurabuchi Town, Takasaki City, Gunma Prefecture, Japan, which is located 100 km north of Tokyo. A prospective cohort study (The Kurabuchi Study) of function and aging was designed, and a baseline survey was performed in 2005-2006 [14-16]. Excluding those who were hospitalized or institutionalized, we identified 1,294 residents as the eligible population, and invited all of them to participate in baseline medical examinations. Of these 1,294 residents, 834 gave written consent and participated in the baseline examinations (participant proportion = 64.5%). Age and sex distribution did not differ substantially between those who participated in the baseline examinations and those who did not. The proportions in the total eligible population of those aged 80 years or older and women were 28.2% and 54.7%, respectively; the corresponding figures for the participants were 26.4% and 58.3% [15]. Of the 834 participants, we excluded 42 who were dependent in ADL at baseline or who did not undergo evaluation of kyphotic posture. As a result, we analyzed data on 792 residents (337 men and 455 women) in the current study.

The Kurabuchi Study protocol was approved by the Ethics Committees of Keio University School of Medicine (Tokyo, Japan) and Toho University School of Medicine (Tokyo, Japan) School of Medicine.

Evaluation of kyphotic posture

Kyphotic posture was noninvasively evaluated by the block method (supine position) and kyphosis index (KI, standing position). For the block method, which measures the distance between the participant's occiput and the table, as originally reported in the Rancho Bernardo Study [7] (Supplementary Figure 1), posture was evaluated on the basis of the number of blocks, each measuring 1.5 cm in height, that could be placed under the neck when the participant was in the supine position with his/her face parallel to the floor. Interrater reliability was reported to be 0.91 [17]. Since very few participants required ≥ 4 blocks (0.13%), kyphosis was classified into four grades based on the number of required blocks: 0, 1, 2, and ≥ 3. With regard to KI, the participant was asked to relax and stand naturally, and the curvature between the spinous processes of the 7th cervical and 4th lumbar vertebrae was traced onto paper with an adjustable curve ruler [18, 19]. KI was then calculated according to the formula shown in Supplementary Figure 1; the reproducibility of this method was 0.78 [18]. No cut-off value for KI has been proposed, so we classified the results into sex-specific quintiles.

Using the results of the block method and KI, we classified kyphotic posture into four types. According to our previous study [11], we defined a block method result of ≥ 3 blocks as "structural curvature" (severe kyphosis even in the supine position). We confirmed that the risk of ADL dependence was increased in the participants with structural curvature (Supplementary Table 1). We divided the participants with block method results of ≤ 2 into three types: “physiological curvature” (mild kyphosis in the supine position with physiological curvature in the standing position), “flat back” (mild kyphosis in the supine position with a straight spine in the standing position), and “postural curvature” (mild kyphosis in the supine position with severe kyphosis only in the standing position). Problems associated with the flat back type have been reported [20], so it was given an independent category. With the median quintile (Q3) set as the reference group, we found, as expected, that not only the highest quintile (Q5) but also the lowest (Q1) showed an increased risk of ADL dependence (Supplementary Table 2). For those with block method results of ≤ 2 blocks, therefore, we defined Q2-4 of the lowest risk of ADL dependence as “physiological curvature type”, Q1 as “flat back type”, and Q5 as “postural curvature type” (Figure 1).

Outcomes

We followed the participants up until March 2014 (mean follow-up: 7.5 years), and collected information on declines in basic ADL from home-visit surveys performed every year; information on nursing home admission, certification of a need for long-term care/support, and death was collected from the Kurabuchi Branch Office of Takasaki City Hall. A decline in basic ADL was defined as the need of partial or full assistance in at least one of the following activities: bathing, dressing, toileting, transferring, continence, feeding [21]. Certification of a need for long-term care or support was based on the criteria used in the Japanese nursing-care insurance system, which started in 2000, and certifications at all seven levels were included.

In this study, we defined ADL dependence as either admission to a nursing home, certification of a need for long-term care/support, or a decline in basic ADL during the follow-up period [16], because the number of participants in each category of ADL dependence was relatively small, and because there were overlaps among the categories.

Covariates

Information was collected via a structured questionnaire on age, sex, educational background (junior high/high school or higher), history of life-threatening disease (stroke, myocardial infarction, angina, diabetes, and cancer), current smoking (yes/no), current alcohol drinking (yes/no), knee pain (none/occasional/sometimes/always), and back pain (yes/no). Body mass index (BMI) was estimated by dividing body weight by the square of height as predicted from the demi-span [22] (<18.5/18.5-24.9/25.0 kg/m^2). To estimate bone density, calcaneal stiffness was measured with an A-1000 Express (GE Yokogawa Medical Systems, Tokyo, Japan) using quantitative ultrasound bone mass measurements. All of these covariates have been reported to be involved in ADL.

Statistical analysis

All analyses were performed with STATA ver14 (STATA, College Station, TX).

The baseline characteristics of the participants were compared among the four kyphotic posture types by chi-square test and one-way analysis of variance. To examine the association of each kyphotic posture with ADL dependence, and death, the odds ratios (ORs) and 95% confidence intervals (CIs) were calculated by logistic regression modelling, with the physiological curvature type used as the reference. Participants who died during the follow-up period were excluded from the analysis of ADL dependence. The strength of the association was presented as the OR and 95% CI. In this study, since the association between kyphotic posture type and ADL dependence did not vary by sex (p for effect modification = 0.13), we treated sex as a confounding factor. Initially, we adjusted for age (65-69, 70-74, 75-79 and over 80 years old) and sex. We additionally adjusted for any history of life-threatening diseases (regarded as a priori adjustment variables), and knee pain and calcaneal stiffness in which differences in distribution were noted among the posture types. Regarding the other covariates in Table 1, we confirmed that their inclusion did not change the results substantially in the multivariate analysis. We also examined the association between kyphotic posture and the 3 components of ADL dependence (basic ADL decline, certification of need for long-term care/support, and admission to a nursing home).

Results

Of the 792 participants, we excluded 6 (0.8%) who had moved out of the town during the follow-up, and analyzed the data on the remaining 786. The incidence of dependence in ADL was 24.7% (n = 194), and the number of deaths was 112 (14.2%) (Supplementary Table 3).

The characteristics of the participants according to the four types of kyphotic posture are shown in Table 1. Physiological curvature was observed in 53.9% of the participants, flat back in 18.4%, postural curvature in 10.9%, and structural curvature in 16.8%. The proportion of participants with postural and structural curvature was increased in the over 80-year age group and the group with always knee pain, and the participants with structural curvature showed lower levels of calcaneal stiffness than those with physiological curvature. No differences were observed in the distributions of sex or other factors according to the type of kyphotic posture.

The associations between the four types of kyphotic posture and ADL dependence and death are shown in Table 2. Flat back and structural curvature were associated with future ADL dependence, but postural curvature was not. Compared with physiological curvature, the multivariate-adjusted OR (95% CI) for flat back was 1.72 (1.04-2.86), and for structural curvature it was 2.76 (1.59-4.79). With regard to each component of ADL dependence, there were no marked differences in the findings for basic ADL, certification of a need for long-term care/support, or admission to a nursing home, but the increased risk of ADL dependence in the flat back group was mainly due to a need for long-term care/support (Figure 2). A weak association between structural curvature and death was observed (multivariate-adjusted OR = 1.59, 95% CI = 0.93-2.72).

Discussion

We found that a flat back and structural curvature that is not corrected in the supine position were associated with ADL dependence, while postural curvature manifesting as severe kyphosis only in the standing position was unassociated, suggesting that the effects of kyphosis on ADL differ according to kyphotic posture. Ailon et al. [23] suggested that the causes of kyphotic deformity in elderly people are multifactorial, and that they include degeneration, spinal compression fracture, and muscle weakness; other investigations have included bony and soft tissue [12, 24]. In a study of 157 postmenopausal osteoporosis patients aged 60 years or older, Miyakoshi et al. [2] classified kyphotic posture in total spine radiograms acquired with participants in the standing position into four types: hump back, swayback, overall kyphosis, and gibbus. QOL was significantly lower in participants with any of these types than in those with a normal spine, and the reduction was particularly marked in participants with the overall kyphosis type. However, their method of classification required radiography, and a simpler method is desirable for wider application. Moreover, their measurements were made only with participants in the standing position, rather than in both the standing and supine positions, as in the current study.

The differences in prognosis according to kyphotic posture require consideration. In elderly people, thoracic kyphosis progresses with aging [25]: the sagittal vertical axis shifts anterior to the spine, the relationship between the center-of-gravity line and heel remains constant, and the pelvis is tilted backward; in other words, kyphotic deformity due to age-related changes may be compensated for [6, 26]. For example, reduced lumbar lordosis with aging is compensated for by backward pelvic inclination and an increase in thoracic kyphosis, and kyphosis is compensated for by pelvic inclination and extension of the hip joint. When spinal balance in the standing position is lost, the muscles of the trunk and four limbs are used to recover balance, and this consumes extra energy and causes fatigue. This concept has been demonstrated in biomechanical studies [27, 28].

In the current study, we defined four types of kyphosis. The risk of future ADL dependence was lowest in the participants with the first type, physiological curvature, so we used this type as a reference. In those with the flat back type, the center-of-gravity line is anterior to the spine, which is probably compensated for by backward pelvic inclination and extension of the hip joint; this results in an overload on the muscles of the back and the region around the hip joint to maintain a standing posture. Persistent muscle fatigue due to this condition reduces ADL because of falls and fractures. This conclusion is supported by the fact that in our study certification of a need for long-term care/support was the dominant factor in increased risk of ADL dependence.

We expected that the third type, postural curvature, would elevate the risk of ADL dependence, but we did not find any association between postural curvature and either ADL dependence or death. By contrast, we did find an association between structural curvature and increased risk of ADL dependence. We do not know why this should be, but we suspect it may be explained by the fact that structural curvature is associated more with osteoporosis and/or sarcopenia than postural curvature; osteoporosis is likely to lead to spinal compression fractures. In a systematic review of the influence of osteoporosis-associated spinal compression fractures and kyphosis on pulmonary function, Harrison et al. [29] showed that the grade of kyphosis was correlated with reductions in vital capacity, and that this was most marked when the kyphosis angle was ≥ 55°. Lee et al. [30] considered spinal compression fractures a serious complication of spinal osteoporosis, pointing out that they are associated with high mortality. We found that calcaneal stiffness was reduced in participants with structural curvature, as compared with those with the other types of kyphosis. Sarcopenia has been reported to be associated with increased risk of disability [31], and Imagama et al. [32] reported that back muscle strength is associated with the physical component of QOL. In our study, however, we obtained no radiographic information (and therefore no data on compression fractures) or muscle volume measurements. Future studies including these assessments are needed.

The current study has several strengths. First, its generality was increased by the fact that the participants were community-dwelling elderly persons, rather than outpatients. Second, the long period of 7.5 years of almost complete follow-up (follow-up rate = 99.2%) enabled us to collect an abundance of information and carry out a detailed investigation of ADL dependence. In addition, assessments by the block method and KI are noninvasive and can be made quickly and easily by non-experts, even at facilities that are not medical care sites. However, our study relied on kyphotic posture classifications that we defined ourselves according to our block method and KI results. Further studies are required to examine whether the kyphotic posture types used in this study are associated with morbidity and mortality in other elderly populations.

There are two additional limitations we must acknowledge. First, we had no information about any therapeutic interventions carried out during the follow-up period, and it is quite possible that some of the participants with severe kyphosis were receiving therapy. However, treatment would have prevented ADL dependence to some extent, so the association we observed between kyphosis and ADL dependence might have been weaker than it would have been if the participants had not been treated. Also, our sample size was too small for us to properly evaluate any sex-specific associations between kyphotic posture type and ADL dependence, although there was a possibility of different associations between the sexes (p for effect modification = 0.13) [33].

In conclusion, our results suggest that the prognosis of people with kyphosis differ according to the type of kyphotic posture.

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Compliance with ethical standards

Ethical approval The study protocol was approved by the Ethics Committees of Keio University (Tokyo, Japan) and Toho University (Tokyo, Japan) School of Medicine. All participants provided written informed consent to participate in the study.

Conflict of interest The authors declare no conflict of interest.

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Table 1 Baseline characteristics of 792 participants according to the four types of kyphotic posture (The Kurabuchi Study 2005-2006)

	Physiological curvature type	Flat back type	Postural curvature type	Structural curvature type	
	Number (%)[a]	Number (%)[a]	Number (%)[a]	Number (%)[a]	P value
Block method (number of blocks)	< 3	< 3	<3	≥ 3	
Kyphosis index, Median (interquartile range)	9.3 (2.3) for men, 9.1 (2.5) for women	5.7 (1.9) for men, 5.5 (1.3) for women	12.9 (1.5) for men, 13.9 (2.4) for women	11.3 (2.9) for men 14.3 (4.6) for women	
Age category (years)					
65-69	105 (24.6)	34 (23.3)	14 (16.3)	19 (14.3)	< 0.001
70-74	132 (30.9)	57 (39.0)	22 (25.6)	24 (18.1)	
75-79	99 (23.2)	35 (24.0)	19 (22.1)	35 (26.3)	
80-	91 (21.3)	20 (13.7)	31 (36.1)	55 (41.4)	
Sex					
Women	255 (59.7)	86 (58.9)	40 (46.5)	74 (55.6)	0.14
Men	172 (40.3)	60 (41.1)	46 (53.5)	59 (44.4)	
Education					
High school or higher	99 (24.0)	39 (27.7)	17 (20.7)	26 (20.5)	0.50
Junior high or below	314 (76.0)	102 (72.3)	65 (79.3)	101 (79.5)	
History of life-threatening diseases[b]					
No	334 (78.2)	112 (76.7)	58 (67.4)	102 (76.7)	0.18
Yes	93 (21.8)	34 (23.3)	28 (32.6)	31 (23.3)	
Current smoking					
No	358 (86.3)	131 (91.6)	69 (83.1)	110 (85.9)	0.26
Yes	57 (13.7)	12 (8.4)	14 (16.9)	18 (14.1)	

Current drinking					
No	275 (66.8)	93 (65.5)	61 (74.4)	90 (70.9)	0.44
Yes	137 (33.3)	49 (34.5)	21 (25.6)	37 (29.1)	
Knee pain					
No	225 (54.7)	76 (53.2)	39 (48.2)	71 (55.9)	< 0.001
Sometimes	96 (23.4)	38 (26.6)	19 (23.5)	16 (12.6)	
Often	43 (10.5)	6 (4.2)	2 (2.5)	12 (9.5)	
Always	47 (11.4)	23 (16.1)	21 (25.9)	28 (22.1)	
Back pain					
No	184 (43.1)	61 (41.8)	31 (36.1)	45 (33.8)	0.22
Yes	243 (56.9)	85 (58.2)	55 (64.0)	88 (66.2)	
BMI (kg/m^2)[c]					
< 18.5	43 (10.1)	10 (6.9)	11 (12.9)	21 (15.8)	0.33
18.5-24.9	271 (63.5)	98 (67.1)	55 (64.7)	79 (59.4)	
≥ 25.0	113 (26.5)	38 (26.0)	19 (22.4)	33 (24.8)	
Calcaneal stiffness[d]					
Mean (SD)	69 (17.7)	73.5 (13.6)	67 (14.8)	62 (17.7)	< 0.001

BMI body mass index, *SD* standard deviation.

[a] Due to missing values, the totals for the stratified subgroups are not equal

[b] Stroke, myocardial infarction, angina, diabetes mellitus, and cancer were included.

[c] BMI was calculated as weight divided by the square of height predicted by demi-span.

[d] Calcaneal stiffness was measured with an A-1000 Express (GE Yokogawa Medical Systems, Tokyo, Japan) using quantitative ultrasound bone mass measurement.

Table 2 Associations of the four types of kyphotic posture with activities of daily living (ADL) dependence and death

Type of kyphotic posture	No. of outcome/ No. of participants (%)	Crude OR (95%CI)	Age and sex adjusted OR (95%CI)	Multivariable adjusted OR (95%CI)[a]
ADL dependence				
Physiological curvature	80/370 (21.6)	1.00	1.00	1.00
Flat back	37/133 (27.8)	1.40 (0.89-2.20)	1.76 (1.07-2.88)	1.72 (1.04-2.86)
Postural curvature	27/71 (38.0)	2.22 (1.30-3.81)	1.81 (0.99-3.31)	1.51 (0.80-2.85)
Structural curvature	50/100 (50)	3.63 (2.28-5.76)	2.95 (1.75-4.96)	2.76 (1.59-4.79)
Death				
Physiological curvature	52/422 (12.3)	1.00	1.00	1.00
Flat back	13/146 (8.9)	0.70 (0.37-1.32)	0.72 (0.37-1.39)	0.81 (0.41-1.58)
Postural curvature	14/85 (16.5)	1.40 (0.74-2.67)	1.06 (0.54-2.07)	0.91 (0.44-1.89)
Structural curvature	33/133 (24.8)	2.35 (1.44-3.83)	1.79 (1.07-2.98)	1.59 (0.93-2.72)

CI confidence interval, *OR* odds ratio.

[a] Age, sex, history of life-threatening diseases (stroke, myocardial infarction, angina, diabetes, and cancer), knee pain, and the calcaneal stiffness were adjusted for.

Figure 1. Occiput to Table Distance, Kyphosis Index and classification of kyphotic posture type

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Occiput to Table Distance</td></tr>
<tr><td>0－2 block</td><td>3 or more</td></tr>
<tr><td rowspan="5">Kyphosis Index</td><td>Q1</td><td>Flat back</td><td rowspan="5">Structural curvature</td></tr>
<tr><td>Q2</td><td rowspan="3">Physiological curvature</td></tr>
<tr><td>Q3</td></tr>
<tr><td>Q4</td></tr>
<tr><td>Q5</td><td>Postural curvature</td></tr>
</table>

Figure 2. Associations of kyphotic posture types with basic ADL, certification of a need for support/long-term care, and admission to a nursing home

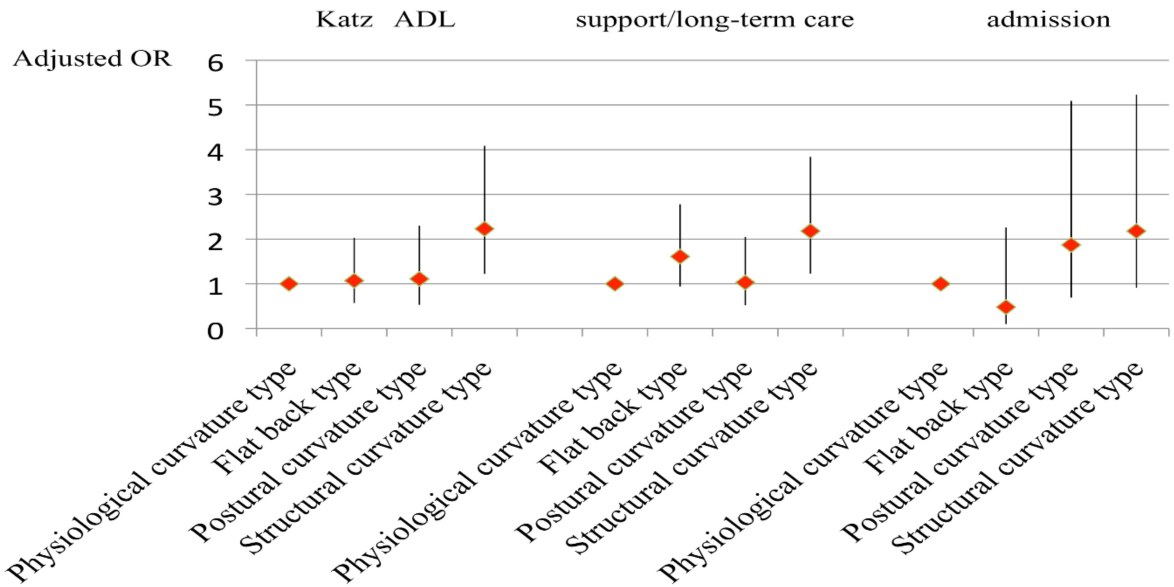

Figure legends

Figure 1 Using the results of the block method and kyphosis index (KI), we classified kyphotic posture into four types.

Physiological curvature: mild kyphosis in the supine position with physiological curvature in the standing position. Flat back: mild kyphosis in the supine position with a straight spine in the supine position. Postural curvature: mild kyphosis in the supine position with severe kyphosis only in the standing position. Structural curvature: severe kyphosis, even in the supine position.

Figure 2 Associations of the four types of kyphotic posture with each component of activities of daily living (ADL) dependence, including basic ADL, certification of a need for support/long-term care, and admission to a nursing home. Odds ratio (OR) was adjusted for age, sex, history of life-threatening diseases (stroke, myocardial infarction, angina, diabetes, and cancer), knee pain, and the calcaneal stiffness.