Table 3
P-values for comparisons between subgroups divided by each lumbar lordosis angle and falls.

Lumbar lordosis (°)	*P*-value[†]
8	0.079
7	0.072
6	0.174
5	0.098
4	0.062
3	0.047*
2	0.023*
1	0.023*
0	0.007*
−1	0.015*

* Statistical significance.
† Univariate logistic regression analyses after adjustment for age and sex.

that angles of lumbar lordosis at 3° and less showed a significant correlation with falls ($P < 0.05$) (Table 3). Thirteen out of fifty four patients (23%) with a lumbar lordosis of 3° and less actually fell in the previous year.

The correlations among age, spinal alignment (thoracic kyphosis, lumbar lordosis, and spinal inclination), LNG, and BES are shown in Table 4. Regarding the sagittal spinal contour parameters, lumbar lordosis showed significant correlations with all the other spinal alignment factors, whereas thoracic kyphosis only showed a weak correlation with lumbar lordosis. Spinal inclination displayed a significant moderate correlation with lumbar lordosis, but not with thoracic kyphosis.

The loss of lumbar lordosis and the angle of spinal inclination showed significant correlations with age, LNG, and BES. In contrast, the angle of thoracic kyphosis showed no significant correlations with age and BES, and an absent correlation with LNG. Age showed a significant positive but weak correlation with LNG and a significant negative moderate correlation with BES. LNG also showed a significant negative moderate correlation with BES.

4. Discussion

Among the previously reported causal factors for falls or fall-related fractures [3], postural instability, which is influenced by loss of lumbar lordosis [12], is considered to be an important risk factor for falls [8–11]. In the present study, sagittal spinal contour factors were evaluated with a computer-assisted device (Spinal-Mouse®), postural instability was assessed using stabilometry, and BES was measured using a strain-gauge dynamometer. These devices are convenient for studies of community-dwelling elders because of their non-invasiveness, ease of handling, and the limited time needed for the measurements. The reliability of this device has already been well described [13–17].

Loss of spinal lordosis, decreasing range of spinal motion, and back muscle weakness have been reported as critical factors for predicting falls [11]. To prevent falls and fractures associated with spinal deformities, and to screen patients with spinal deformities who might require further medical care, determination of a cut-off angle of spinal contour associated with falls would improve clinical management. Lumbar lordosis was found to be the most significant factor associated with falls in the present study, and the critical cut-off value of lumbar lordosis associated with falls was 3° or less. This angle can be used during medical checkups to screen subjects who are suspected to be at risk for falling.

X-rays, the gold standard for evaluation of sagittal spinal alignment, involves radiation exposure, and incurs higher medical costs. Screening subjects at high-risk for falls is a very important issue from the viewpoint of preventive medicine, prevention of fractures, and reduction of medical costs. Therefore, Spinal-Mouse®, which uses surface-based techniques to record spinal contours, requires little time to calculate spinal angle and requires no radiation exposure or cost to the patient, is useful and suitable for medical checkups and outpatient clinics.

Younger subjects are at less risk of falls than older subjects, and usually do not show any apparent degenerative spinal deformities. Therefore, only subjects aged 55–85 years, who had a tendency to fall and who were thought to be potential candidates for further medical care, were included in this study. Consistent with a previous report [12], we found that loss of lumbar lordosis had a significant correlation with age, while thoracic kyphosis did not. Lumbar lordosis, but not thoracic kyphosis, also showed a significant correlation with spinal inclination, and leads to an increased forward bending posture that may be related to falls. As reported previously [11], postural imbalance indicated by LNG, X LNG, and Y LNG showed a significant correlation with falls. BES also showed a significant association with falls. Moreover, BES showed a significant negative correlation with LNG, suggesting that weakness of BES would increase postural sway and imbalance, and contribute to the risk of falls.

Thoracic or thoracolumbar kyphosis is commonly accepted as the first deformity in elderly people [18]. Progression of the thoracic kyphosis by the flexor moment with anterior movement of the center of gravity aggravates the deformity. In elderly people, lumbar mobility was more severely limited because of spondylosis [19,20] and weakness of BES with aging [21] (Table 4). Consequently, compensation for thoracic kyphosis by the lumbar spine may be inhibited, thereby progressing the loss of lumbar lordosis, and the additional deformity may induce lumbar kyphosis [22]. On the other hand, severe thoracic kyphosis may be inhibited by the ribcage anatomically, such that the spinal inclination may increase significantly and be correlated with loss of lumbar lordosis, but not thoracic kyphosis, with aging as shown in Table 4. Loss of lumbar lordosis increases a forward bending posture (spinal inclination), which may induce anterior deviation of the center of gravity, postural instability, and falls.

The normal sagittal spinal contour shows thoracic kyphosis and lumbar lordosis, and the thoracic back muscles are thinner than the lumbar back muscles anatomically. Therefore, the BES measured in the present study is supposed to be mainly derived from the

Table 4
Correlations among age, spinal sagittal contour, LNG, and BES.

	Thoracic kyphosis (°)	Lumbar lordosis (°)	Spinal inclination (°)	LNG (mm)	BES (kg)
Age	0.031	−0.359**	0.457**	0.388**	−0.514**
Thoracic kyphosis (°)		0.286**	0.004	−0.177*	0.107
Lumbar lordosis (°)	0.286**		−0.542**	−0.396**	0.424**
Spinal inclination (°)	0.004	−0.542**		0.505**	−0.547**
LNG (mm)	−0.177*	−0.396**	0.505**		−0.394**
BES (kg)	0.107	0.424**	−0.547**	−0.394**	

Notes: BES, back extensor strength; LNG, total track length. Data represent Pearson's correlation coefficients (*r*).
* $P < 0.05$.
** $P < 0.001$.

lumbar extensor muscles, and this may also explain the significant correlation observed between the BES and lumbar lordosis.

The cut-off value for falls in the present study was 3° of lumbar lordosis. However, the loss of lumbar lordosis increased with aging. Some previous reports have also described that sway increases with age and is higher in women at all ages [23,24]. Further investigations will clarify the differences with other generations and/or sex.

The results of the present study show that age, lumbar lordosis, spinal inclination, LNG, X LNG, Y LNG, and BES may represent risk factors for falls. Moreover, loss of lumbar lordosis was the most significant spinal parameter correlating with falls. Precise analyses revealed that patients with an increased incidence of falls tend to have lumbar lordosis of 3° or less in this community-dwelling study. Patients with loss of lumbar lordosis should be advised of their increase risk of falling and should be considered for enrollment in a fall prevention program.

Acknowledgment

None.

Conflict of interest statement

None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.gaitpost.2012.11.024.

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Spinal Posture in the Sagittal Plane Is Associated With Future Dependence in Activities of Daily Living: A Community-Based Cohort Study of Older Adults in Japan

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Background. Accumulated evidence shows how important spinal posture is for aged populations in maintaining independence in everyday life. However, the cross-sectional designs of most previous studies prevent elucidation of the relationship between spinal posture and future dependence in activities of daily living (ADL). We tried to clarify the association by measuring spinal posture noninvasively in a community-based prospective cohort study of older adults, paying particular attention to thoracic curvature, lumbar curvature, sacral hip angle, and inclination to determine which parameter is most strongly associated with dependence in ADL.

Methods. Spinal posture was evaluated in 804 participants (338 men, 466 women, age range: 65–94 years) who were independent in ADL at baseline. We defined dependence in ADL as admission to a nursing home or need of home assistance. During the 4.5-year follow-up period, 126 (15.7%) participants became dependent in ADL. The relationship between the spinal posture parameters and outcome was assessed by dividing the participants into sex-specific quartiles of the parameters.

Results. Only inclination (angle subtended between the vertical and a line joining C7 to the sacrum) was associated with outcome, although lumbar curvature also showed a marginal association. The age- and sex-adjusted odds ratio for a 1 unit increase in the quartiles of inclination was 1.79 (confidence interval: 1.44, 2.23). After mutual adjustment for the 4 parameters, statistical significance for inclination still remained, with no substantial changes in the association estimates.

Conclusions. This study indicates that spinal inclination is associated with future dependence in ADL among older adults.

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POPULATIONS are aging rapidly worldwide. This trend is particularly evident in Japan, whose population has the world's longest life expectancy (79.4 years for men and 85.9 years for women (1)). The already rapid pace at which society is aging is expected to accelerate further, meaning that fewer young people will be available to take care of the elderly people, and thus making it even more important for the elderly people to be able to live independent and active lives.

Spinal posture changes with age, but accumulated evidence shows that continued good spinal posture is important in allowing the aged to maintain independent lives (2,3). Hirose and colleagues (4) reported that the posture of the trunk in the sagittal plane is associated not only with the distance and time parameters of gait, but also with functional performance in the elderly population. In a study by Takahashi and colleagues (5), participant groups with trunk deformities tended to score lower than the control group on subjective healthiness and life satisfaction measures. However, the cross-sectional designs of most studies to date prevent conclusions being drawn about the relationship between spinal posture and future dependence in activities of daily living (ADL). The participants of these studies were patients with spinal deformities and diagnoses of osteoporosis, and evidence is lacking from community-based studies.

Determination of spinal posture requires the examination of multiple elements, including the cervical vertebrae, thoracic vertebrae, lumbar vertebrae, and pelvis. Because such examinations have generally been done with x-ray equipment, they have not been carried out at local health facilities due to the lack of specialized equipment. In recent years, however, a computer-assisted and easily operated, noninvasive, portable device to measure spinal shape has been developed (6,7). With this device, sagittal spinal curve divided into thoracic curvature, lumbar curvature, sacral hip angle, and inclination can be examined. We used the device in this study to examine spinal posture noninvasively in older adults and tried to clarify the association between spinal posture and future dependence in ADL through a community-based prospective cohort study design. We paid particular attention to thoracic curvature, lumbar curvature, sacral hip angle, and inclination to determine which of these four parameters is most strongly associated with dependence in ADL.

Methods

Study Population

The Kurabuchi Study, a community-based prospective cohort study of aging involving functional assessment of an older population, was launched in 2005 (8,9). Briefly, the study population included all residents aged 65 years or older of Kurabuchi Town, Gunma Prefecture (approximately 100 km north of Tokyo, Japan). Excluding those who were hospitalized or institutionalized, a total of 1,294 residents, were eligible for inclusion in the study. Of these, 834 participated in the baseline examination (participant proportion = 64.5%) and gave written informed consent. For the purposes of this study, we excluded those who were dependent in ADL at the baseline (n = 29) and those who did not undergo spinal curvature measurements (n = 1). Thus, a total of 804 participants (338 men and 466 women) were subject to the study. The study protocol was approved by the Ethics Committee of the School of Medicine, Keio University (Tokyo, Japan) and by that of Toho University (Tokyo, Japan).

Assessment of Spinal Posture

The participants were asked to stand in a relaxed position wearing one layer of clothing, and spinal posture was evaluated with a Spinal Mouse (Indiag, Volkerswill, Switzerland), a computer-assisted, noninvasive device for measuring spinal shape. The device is guided along the midline of the spine, starting at the spinous process at C7 and finishing at the top of the anal crease (approximately S3). Measurements were repeated 3 times, and the best two values were averaged. The relevant parameters recorded with the Spinal Mouse were thoracic curvature (Th1-2 to Th11-12), lumbar curvature (Th12–L1 to the sacrum), sacral hip angle (angle between a straight line from S1 to S3 and true vertical), and trunk angle of inclination (angle between a straight line from Th1 to S1 and true vertical (6)), as shown Figure 1. The larger the figures for thoracic and lumbar curvature measurements were, the greater the degree of kyphosis. The sacral hip angle and inclination measurements reflected forward pelvic tilt and forward stooped posture.

The intraexaminer reliability and interexaminer reliability of the Spinal Mouse were high in terms of intraclass correlation coefficients: 0.82–0.95 (6,7) and 0.81–0.86 (7), respectively.

Outcome Measurements

We defined dependence in ADL as either admission to a nursing home or need of assistance at home during the follow-up period (10). The latter was defined as long-term care (LTC) eligibility or a need for help in any of the six basic ADL items in the Katz Index of independence in ADL (11). LTC eligibility is a requirement for receiving LTC insurance services in Japan, which began in 2000. In this study, any of the seven levels of LTC insurance services was considered LTC eligible. Information on death, nursing home admission, and LTC eligibility was obtained from the Kurabuchi Branch Office of Takasaki City Hall. Information on Katz ADL was obtained from repeat face-to-face home interviews conducted every year until 2010 by public health nurses and local welfare commissioners, and occurrence of ADL dependence in any year was defined as dependence in ADL.

Covariates

We collected information on age, sex, smoking status (current vs former or never), alcohol drinking (current vs

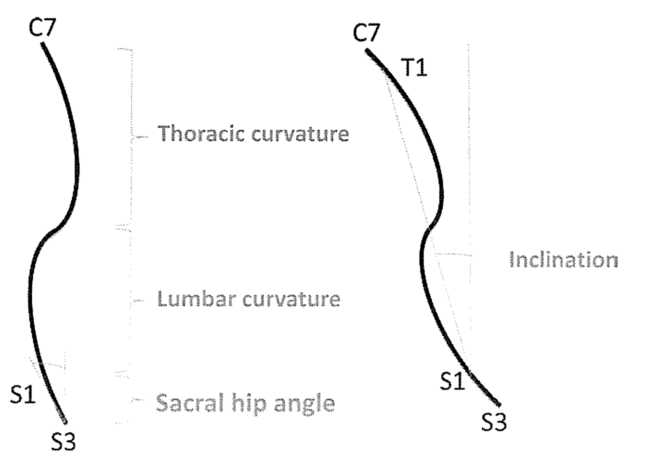

Figure 1. A schema illustrating the four parameters. Thoracic curvature: thoracic kyphosis (corresponds to Cobb angle between Th1 and Th12). Lumbar curvature: lumbar kyphosis (corresponds to Cobb angle between Th12 and S1). Sacral hip angle: the angle between a straight line from S1 to S3 and true vertical. Inclination: the angle between a straight line from Th1 to S1 and true vertical.

former or never), educational level (junior high vs high school or higher), back pain, including low back pain (yes or no in the past year), knee joint pain (never vs occasionally vs often vs always), and current or past history of life-threatening diseases, including stroke, myocardial infarction/angina, diabetes mellitus, and cancer (summary answer of yes or no). Body mass index was calculated as weight (kg) divided by the square of height (m) predicted by demi-span (12) and then categorized (<18.5 vs 18.5–24.9 vs 25≤ kg/m^2). Estimated bone mineral density was assessed from calcaneal quantitative ultrasound measurements made with an A-1000 Express (GE Yokogawa Medical Systems, Tokyo, Japan) and expressed as a stiffness index. All of the above covariates have been reported to be involved in ADL dependence outcomes.

Statistical Analysis

All analyses were performed with STATA version 12 (STATA Corporation, College Station, Texas).

Distributions of the four parameters of spinal posture were calculated according to age and sex. Trends by age category were examined with logistic regression, with consecutive integers given to each category. The relationships between the spinal posture parameters and outcomes were assessed by dividing the participants into sex-specific quartiles. First, age-category (5-year increments) and sex-adjusted analyses were carried out with logistic regression models. Then, other covariates (education, current/past history of life-threatening diseases, knee joint pain, and body mass index category) were included in the models (Model 1). Smoking and drinking status were not included because they were not associated with outcomes in this study. Second, a model mutually adjusted for all four parameters of spinal posture (Model 2) was applied. Additionally, models including back pain and stiffness were applied to Model 2 (Model 3). Trends across increasing quartiles of the parameters were also calculated by treating the quartiles as an integral value. Because there was no interaction by sex, all analyses were carried out with combined data for men and women. This analytic method was repeated for dependence in ADL and for the composite outcome of dependence in ADL and death. Participants who died during the follow-up period were excluded from the analysis of dependence in ADL. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were used to describe the strengths of associations.

Results

During the 4.5-year follow-up period, 126 (16.4%) participants became dependent in ADL, 61 (7.6%) died, and 6 (0.7%) moved out of the town. Table 1 shows the characteristics of the study participants. Those in their seventies constituted the majority and women made up to 58%. The distributions of the four parameters of spinal posture are presented in Table 2. The effect of age on thoracic curvature seemed to vary between men and women. In men, thoracic kyphosis decreased with age, whereas it appeared to increase with age in women. However, the trend was not statistically significant. Lumbar lordosis decreased and inclination increased with age in both men and women.

Table 1. Characteristics of the Study Participants (*n* = 804; Kurabuchi Study 2005)

		n (%)*
Age category (y)	65–69	174 (21.7)
	70–74	237 (29.5)
	75–79	193 (24.0)
	80–84	137 (17.0)
	85	63 (7.8)
Sex	Men	338 (42.0)
	Women	466 (58.0)
Current smoking	Yes	101 (12.9)
	No	680 (87.1)
Current drinking	Yes	245 (31.6)
	No	530 (68.4)
Education	High school or higher	182 (23.5)
	Junior high school or below	593 (76.5)
History of life-threatening diseases†	Yes	189 (24.5)
	No	582 (75.5)
Back pain	Yes	480 (59.7)
	No	324 (40.3)
Knee joint pain	Never	419 (54.1)
	Occasionally	170 (22.0)
	Often	63 (8.1)
	Always	122 (15.8)
BMI category (kg/m^2)‡	<18.5	87 (10.8)
	18.5–24.9	511 (63.6)
	≥25	205 (25.5)
Stiffness	Mean (*SD*)	71.4 (16.8)

Notes: SD = standard deviation; BMI = body mass index.

*Due to missing values, the totals for the stratified subgroups are not equal.

†Stroke, myocardial infarction or angina, diabetes mellitus, and cancer were included.

‡BMI was calculated as weight (kg) divided by the square of height (m) predicted by demi-span (12).

The associations of the four parameters of spinal posture with future dependence in ADL are summarized in Table 3. In Model 1, only inclination was associated with outcome, although lumbar curvature and sacral hip angle showed marginal associations. When the lowest quartile of inclination was used as a reference, the adjusted ORs (95% CI) for the second, third, and highest quartiles were 1.46 (0.60, 3.59), 3.90 (1.76, 8.63), and 4.93 (2.23, 10.91), respectively. The adjusted OR for a 1 unit increase in the quartiles of inclination was 1.75 (1.39, 2.20). Even when inclination was included in the model as a continuous variable, the adjusted OR for a 1 unit increase in inclination was 1.04 (1.02–1.06). In the model where the four parameters were mutually adjusted (Model 2), statistical significance for inclination was maintained, and the association estimates did not change substantially. When back pain and stiffness were added as covariates, the ORs were essentially the same as those in

Table 2. Distributions of the parameters of spinal curvature by age and sex

Age category (y)	n	Thoracic curvature Median (25, 75 percentiles)	Lumbar curvature Median (25, 75 percentiles)	Sacral hip angle Median (25, 75 percentiles)	Inclination Median (25, 75 percentiles)
Men & Women (n = 804)					
65–69	174	44 (37, 50)	−13.5 (−22, −4)	7 (1, 13)	7 (5, 11)
70–74	237	41 (32, 49)	−10 (−18, 0)	7 (0, 12)	9 (6, 11)
75–79	193	43 (35, 50)	−5 (−15, 6)	6 (0, 12)	12 (8, 17)
80–84	137	40 (30, 49)	0 (−11, 10)	4 (−2, 12)	13 (9, 22)
85–	63	44 (30, 54)	−2 (−14, 15)	5 (−1, 14)	16 (10, 29)
trend*		$p = 0.234$	$p < 0.001$	$p = 0.083$	$p < 0.001$
Men (n = 338)					
65–69	74	47.5 (40, 54)	−14.5 (−24, −4)	4.5 (1, 14)	8 (6, 12)
70–74	103	41 (31, 49)	−10 (−17, −1)	6 (0, 13)	9 (7, 12)
75–79	82	43.5 (36, 49)	−8 (−17.5, 3)	7 (0, 12)	12 (7, 16)
80–84	54	40 (29, 48)	0 (−9, 9)	3.5 (−2, 12)	11 (8, 20)
85–	25	39 (29, 51)	−2 (−14, 17)	4 (1, 12)	10 (9, 21)
trend*		$p < 0.001$	$p < 0.001$	$p = 0.172$	$p < 0.001$
Women (n = 466)					
65–69	100	41 (35, 48.5)	−13 (−21.5, −3.5)	8.5 (3, 12.5)	7 (4, 11)
70–74	134	41 (32, 50)	−10 (−18, 3)	7 (0, 11)	9 (6, 13)
75–79	111	43 (32, 50)	−4 (−14, 8)	5 (0, 13)	12 (9, 18)
80–84	83	42 (34, 51)	1 (−14, 12)	4 (−1, 13)	14 (9, 23)
85–	38	45 (33, 58)	−2.5 (−16, 14)	5.5 (1, 14)	17 (13, 29)
trend*		$p = 0.173$	$p < 0.001$	$p = 0.277$	$p < 0.001$

*Trend was examined by scoring the age category (1 to 5) as a continuous term in the regression analysis.

Table 3. Associations of the parameters with dependence in activities of daily living

		Median (25, 75 percentiles)	n/N (%)	Age- & sex-adjusted OR (95% CI)	Adjusted OR (95% CI) Model 1*	Adjusted OR (95% CI) Model 2**	Adjusted OR (95% CI) Model 3***
Thoracic curvature	Q1	27 (22, 30)	29/168 (17.3)	1.00	1.00	1.00	1.00
	Q2	38 (36, 40)	38/183 (20.8)	1.73 (0.96–3.10)	1.81 (0.98–3.34)	2.04 (1.05–3.96)	2.05 (1.05–4.00)
	Q3	45 (44, 48)	30/188 (16.0)	1.17 (0.64–2.14)	1.17 (0.62–2.20)	1.37 (0.68–2.76)	1.42 (0.70–2.85)
	Q4	56 (52, 61)	29/198 (14.7)	0.94 (0.51–1.71)	0.75 (0.39–1.44)	0.92 (0.43–1.96)	0.89 (0.41–1.92)
	one unit increase in the quartiles			0.94 (0.79–1.13)	0.89 (0.73–1.08)	0.98 (0.77–1.23)	0.97 (0.77–1.23)
Lumbar curvature	Q1	−24 (−28, −20)	20/188 (10.6)	1.00	1.00	1.00	1.00
	Q2	−12 (−15, −10)	24/194 (12.4)	1.07 (0.55–2.08)	1.20 (0.60–2.42)	1.07 (0.47–2.44)	1.08 (0.47–2.46)
	Q3	−2 (−4, 0)	39/186 (21.0)	1.77 (0.95–3.30)	1.72 (0.89–3.33)	1.50 (0.57–3.98)	1.47 (0.55–3.93)
	Q4	13 (8, 28)	43/169 (25.4)	1.65 (0.88–3.07)	1.71 (0.88–3.33)	1.52 (0.47–4.92)	1.38 (0.42–4.50)
	one unit increase in the quartiles			1.22 (1.00–1.48)	1.21 (0.99–1.48)	1.20 (0.81–1.76)	1.17 (0.79–1.72)
Sacral hip angle	Q1	−5 (−9, −2)	28/165 (17.0)	1.00	1.00	1.00	1.00
	Q2	3 (1, 4)	32/189 (16.9)	1.10 (0.61–2.00)	1.20 (0.65–2.24)	1.27 (0.62–2.61)	1.28 (0.62–2.62)
	Q3	9 (7, 11)	27/198 (13.6)	1.14 (0.61–2.11)	1.17 (0.60–2.26)	1.32 (0.56–3.14)	1.22 (0.51–2.93)
	Q4	16 (15, 20)	39/185 (21.1)	1.63 (0.91–2.92)	1.83 (0.98–3.42)	2.26 (0.87–5.85)	2.20 (0.84–5.73)
	one unit increase in the quartiles			1.17 (0.97–1.41)	1.20 (0.98–1.47)	1.30 (0.95–1.78)	1.29 (0.94–1.77)
Inclination	Q1	4 (3, 6)	10/185 (5.4)	1.00	1.00	1.00	1.00
	Q2	8 (7, 9)	15/180 (8.3)	1.48 (0.63–3.48)	1.46 (0.60–3.59)	1.34 (0.54–3.33)	1.43 (0.57–3.57)
	Q3	12 (11, 13)	42/199 (21.1)	3.71 (1.75–7.85)	3.90 (1.76–8.63)	3.32 (1.43–7.69)	3.28 (1.41–7.62)
	Q4	20 (16, 27)	59/173 (34.1)	5.30 (2.51–11.18)	4.93 (2.23–10.91)	3.65 (1.43–9.37)	3.47 (1.35–8.93)
	one unit increase in the quartiles			1.79 (1.44–2.23)	1.75 (1.39–2.20)	1.67 (1.25–2.23)	1.62 (1.21–2.17)

Notes: OR: odds ratio, CI: confidence interval.
In this analysis, residents who died during the follow-up period (n = 61) were excluded.
*Age category, sex, educational category, history of life-threatening diseases (stroke, myocardial infarction/angina, diabetes mellitus, and cancer), knee joint pain and body mass index category were adjusted for.
**In addition to the variables included in Model 1, all parameters (thoracic curvature, lumbar curvature, sacral hip angle, inclination) were mutually adjusted.
***Back pain and stiffness were added to Model 2.

Model 2. When the analysis was repeated for the composite outcome of dependence in ADL and death, the association of inclination with outcome was only slightly attenuated and remained statistically significant. The adjusted ORs for 1 unit increases in the quartiles of inclination were 1.52 (1.19, 1.93) in Model 2 and 1.50 (1.18, 1.91) in Model 3 for the composite outcome of dependence in ADL and death.

Discussion

We evaluated four parameters of spinal posture (thoracic curvature, lumbar curvature, sacral hip angle, and inclination) in older adults and demonstrated for the first time, after 4.5 years of follow-up, that of the four parameters, inclination has the greatest effect on dependence in ADL with no clear threshold. We showed too that this association was independent of back pain and estimated bone mineral density. Our results indicate that attention needs to be paid to inclination in spinal posture to identify elderly people at high risk of becoming dependent in ADL.

Many reports have indicated that posture of the trunk in the sagittal plane is associated with body function and dependence in ADL. Various methods of measuring spinal posture were used in these studies. Leech and colleagues (13) and Lombardi and colleagues (14) measured the Cobb angle to assess kyphosis, and reported that hyperkyphosis might be associated with pulmonary function. In another study, participants lay supine with the neck in a neutral position and occiput to table distance was measured with 1.7-cm blocks placed between the head and the examination table; moderate hyperkyphotic posture was found to indicate an increased risk of injurious falls in older men, with a less pronounced association in older women (15). Ryan and colleagues (16) evaluated kyphosis through measurement of the distance between the occiput and a wall, finding that kyphosis is associated with ADL decline. Takahashi and colleagues (5) examined sagittal spinal posture using lateral-view photographs of the participants and found that groups with trunk deformities tended to score lower than the control group on subjective measures of healthiness and life satisfaction. The abovementioned methods of kyphosis assessment are easy and useful, requiring no medical information from local health centers. However, they evaluate spinal posture as a whole, making assessment of each composite parameter of spinal posture impossible. We overcame this disadvantage by using a noninvasive device for measuring spinal shape that has been developed in recent years, the Spinal Mouse.

In our study, mutual adjustment for the four parameters of spinal posture showed that only inclination is associated with future dependence in ADL. Other cross-sectional studies using the Spinal Mouse may help explain this association. Sakamitsu and colleagues (17) used the Spinal Mouse to measure balance (1 ft standing with eyes open) and gait (walking speed in 10-m walk and walking distance in 3 min) in 28 elderly people. They concluded that the larger the anterior inclination of the trunk, the greater the decline in balance and gait skills was. A study by Ishikawa and colleagues (18) of 93 osteoporotic patients with a mean age of 70 years showed that forward spinal inclination with a forward stooped posture affected postural balance. It is reasonable to suppose, therefore, that declines in balance and gait skills caused by inclination lead to falls and fractures, and that these negative outcomes in turn lead to dependence in ADL among elderly people. In fact, data exist to show that community-dwelling women with osteoporosis and hyperkyphosis have weaker back extensor strength, weaker lower extremity strength, slower gait, poorer balance, and greater body sway, which as a result gives them a propensity to fall (19).

The line of gravity line moves naturally with changes in spinal alignment (20–22). Arita and colleagues (23) reported that the center of gravity runs anterior to L4-5 and 6 mm anterior to the hip joint in most elderly people, and another study showed that the center of gravity runs anterior to L4 in healthy elderly people (24). The gravity line moves further anterior as inclination of the trunk increases.

In one study, full-length, free-standing radiographs of the spine and pelvis were examined in 125 adult patients with spinal deformities. The study demonstrated that the T1 spinopelvic inclination (the angle between the T1-hip axis and vertical) correlated with Health-Related Quality of Life measures (25). In another study, 752 patients with spinal deformities were enrolled from a multicenter prospective database. Positive sagittal balance was defined as an anterior deviation of the plumb line from the seventh cervical spinous process. This study showed that although even mildly positive sagittal balance is somewhat detrimental, the decline in health status increases in a linear fashion with progressive sagittal imbalance (26).

Some reports in Japanese indicated that lumbar lordosis decreased with increase in age (27,28) and our results supported these earlier studies. Lumbar lordosis is also reported to be associated with decline in walking ability and in muscle power of lower limb (28–30). In this study, however, lumbar curvature only showed a marginal association with future dependence in ADL. If we included inclination in the model, this association disappeared. Whereas, thoracic kyphosis decreased with age among men. Among women, on the contrary, thoracic kyphosis tended to increase with age as reported in other studies (2,29,31). Although we could not explain this sex difference, thoracic kyphosis might decrease as a compensation for the decrease in lumbar lordosis in men. These potential difference between Japanese and people in other countries and between men and women needs further study.

Although we examined only spinal posture in this study, we recognize that examination of lower limb alignment is also important because changes in spinal posture can influence the alignment of the legs: burdens requiring more than the normal compensatory reactions can lead to joint diseases such as osteoarthritis, which in turn lead to declines in

ADL. Such being the case, future studies including evaluations of lower limb alignment are necessary. Although the Spinal Mouse method was easy and useful for evaluating sagittal spinal posture as a whole, it does not seem to be a reliable tool yet for measuring intersegmental spinal range of motion (7). Furthermore, the Spinal Mouse method does not measure spinopelvic alignment. When sagittal unbalance is detected with Spinal Mouse method, therefore, we recommend full x-ray investigation for evaluating spine and pelvis. Another limitation of our study is that we focused only on sagittal spinal posture. Differences in body sizes and lifestyles also mean that caution is necessary in applying our results to other populations. However, we believe our conclusion that inclination is associated with future dependence in ADL among older adults warrants wide attention.

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整・災外 55：1651－1657，2012

特集 骨・関節疾患の疫学研究の現状と今後

介護予防と脊柱後弯姿勢

西脇祐司[*1)] 道川武紘[*2)]

要旨：わが国は世界一のスピードで高齢化を突き進んでおり，要介護者も年々増加傾向である。今後いかに要介護者への移行や，介護程度の悪化をくい止めるかが喫緊の課題である。この目的達成のために地域保健の現場で把握可能な要介護リスク要因の抽出が求められている。背中の曲がり，いわゆる後弯変形は高齢者に多くみられるコンディションであり，X線を使わない評価方法も複数報告されている。後弯指数，occiput-to-table distance，外観による評価などである。また，後弯が将来のADL低下や死亡に影響するとのエビデンスが集積しつつある。したがって後弯は，地域保健の現場で把握可能なfrailty（虚弱）の指標として有用である可能性がある。しかしながら，後弯そのものが介入によって改善可能かどうかに関してはエビデンスがほとんどなく，今後の課題である。

はじめに

わが国において65歳以上が総人口に占める割合は，平成23(2011)年度で23.3%，平成47(2035)年には33.4%とも予想されている。高齢化率が高いだけでなく，その進行のスピードにおいても日本は際立っている。一方で少子化が改善しない現状にあっては，高齢者自身が自立した，第三者に依存しない生活を営んでいくことが求められている。

介護保険は平成12（2000）年に始まったが，開始当初218万人だった要介護者は，平成24(2012)年度には500万人を超した。少しでも要介護者の増加を抑制するために，いわゆる介護予防事業が開始されたが，その効果も十分に果たされているとは言えないのが現状である。将来要介護者となることを予測するリスク因子の確立とその因子への対策が必要である。

そのリスク因子の一つとして，筆者らは脊柱の姿勢に着目した。特に背中の曲がり，いわゆる後弯変形と将来のADL低下との関連に関して，地域在住高齢者を対象に一連の研究を実施してきた。後弯変形は，高齢者に多くみられるコンディションであり，また外観でわかるため，特別な整形外科的知識を有しない者でも判定が可能であるとすれば，その評価は地域保健の現場向きといえる。そこで本稿では，脊柱姿勢，特に後弯変形について，その計測法について概説し，また死亡，ADL低下といったアウトカムとの関連等を自らの研究結果もご紹介しながら述べてみたい。

Ⅰ．脊柱後弯変形の計測

脊柱の後弯変形を評価する方法としては，X線

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Activity of daily living and kyphotic posture

Key words：Kyphosis，Activity of daily living，Posture

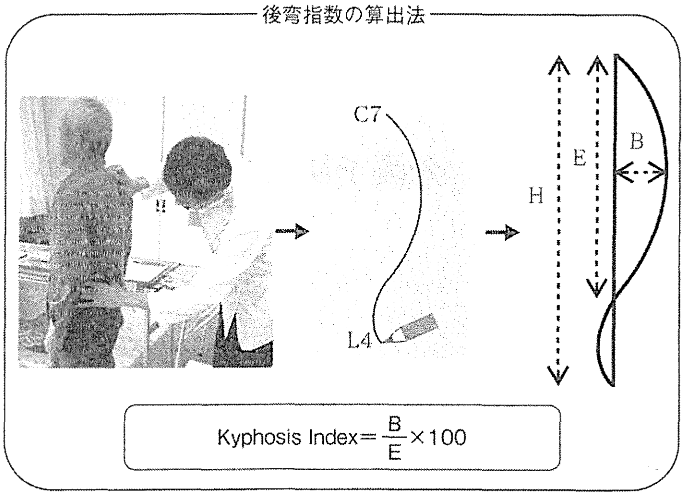


図 1　後弯指数（kyphosis index）の測定

により Cobb 角を計測する方法が整形外科医には最も一般的であろう。しかし当然のことながら，この方法は X 線設備のあるクリニックベースでの使用に限定される。地域保健の現場で，より多くの者を対象に評価を実施したいと考えれば，より簡便に実施できる測定法が求められる。そこで本稿では，X 線撮影の不要な後弯変形の計測方法を紹介する。

1．後弯指数

Milne ら[1] の提唱による方法である。鉛の入った自在定規を背中に当て，第 3 頚椎から腰仙関節までの形状をトレース紙に写す。そのカーブの形状をもとに，図 1 に示した方法で後弯指数（kyphosis index）を算出する。65 歳以上の地域在住住民 536 名を対象とした研究では，この後弯指数は女性において年齢とともに増加していた[2]。薄い着衣であれば着たままでも十分測定可能である。

2．Occiput to table distance（OTD）

胸椎部後弯があると，仰臥位に寝たときに後頭部が下がり，顔面がのけぞった形になる（図 2）。これを顔面が床と水平になるまで後頭部にブロックを入れていき，そのときの必要ブロック数をもって後弯の程度を表そうとした方法が OTD 法である[3]。Kado ら[3] は，1.7 cm のブロックを使用

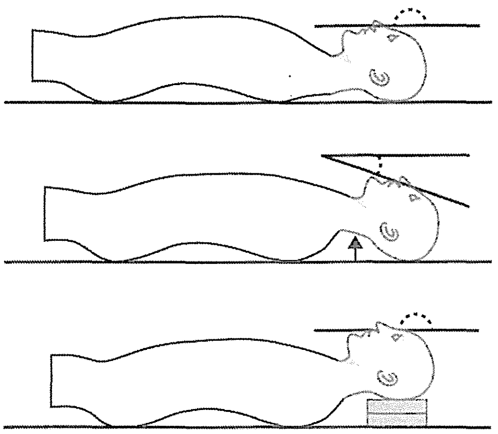


図 2　Occiput-to-table distance の測定

しているが，われわれは日本人の体格を考慮し，1.5 cm のブロックを使用している。

地域在住高齢者 444 名の検討では，図 3 に示したとおり，1 ブロック以上必要だった者の割合は，男女とも 60 代，70 代，80 代と年代とともに増加した（男性：77.4%，79.4%，89.4%，女性：50.9%，54.2%，78.2%）。さらに後弯指数との相関はおおむね良好であり，Spearman の相関係数は男性で 0.54（$p<0.001$），女性で 0.62（$p<0.001$）であったが（図 4），一部乖離例もみられた。後弯指数は立位での測定であり，一方の OTD は仰臥位での

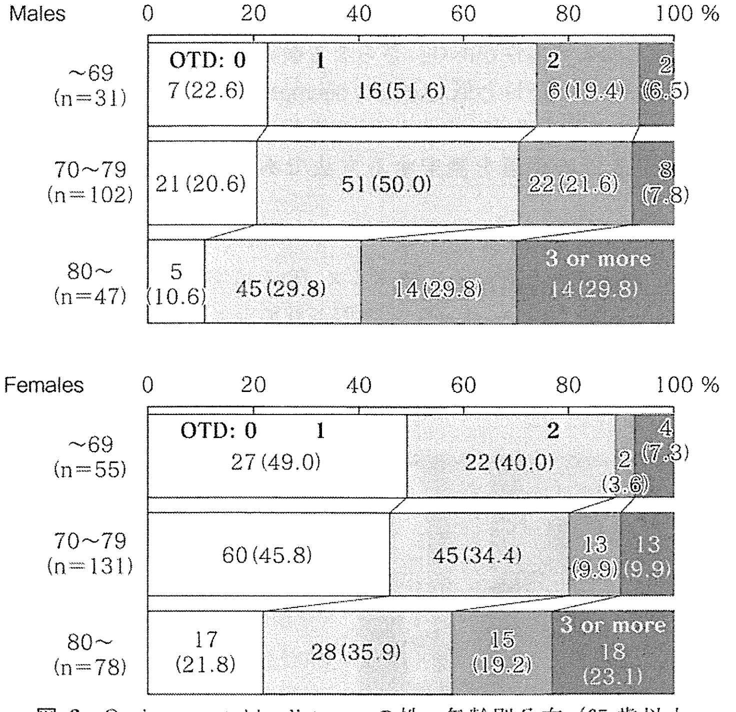


図 3 Occiput-to-table distance の性・年齢別分布（65 歳以上 444 名のデータ）

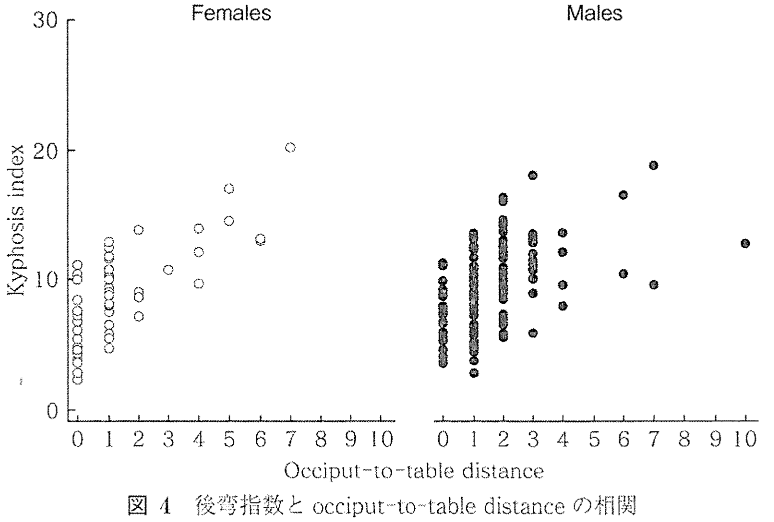


図 4 後弯指数と occiput-to-table distance の相関

測定である。主原因が圧迫骨折などの骨性である場合には後弯指数も OTD も大きくなるのに対し，筋力低下等の軟部組織性の structural な後弯の場合には，後弯指数は大きいが仰臥位測定の OTD は小さくなる可能性が考えられる。このように後弯指数と OTD の組み合わせによる分類

は，今後背筋トレーニング等の介入効果を予測する場合に有用となる可能性があり，さらなる検討が必要である。なお，OTD と似た方法に occiput-to-wall distance 法もあるが，これは床の代わりに立位での壁までの距離を測定する方法である[4]。

3．脊柱形状測定デバイス

非侵襲的に脊柱形状を計測するデバイス（Spinal Mouse；Idiag 社，Switzerland）も市販されている。図5に示すように，ちょうど PC のマウスのような形状のデバイスを背中の弯曲に沿ってなぞることにより，脊柱形状を PC 上に取り込むことができる。さらに付属のソフトにより，胸椎部弯曲，腰椎部弯曲，仙骨傾斜角，脊柱前傾度などが分析可能となっている。上半身裸での計測が理想的だが，薄い着衣であればほとんど測定値に影響はない。

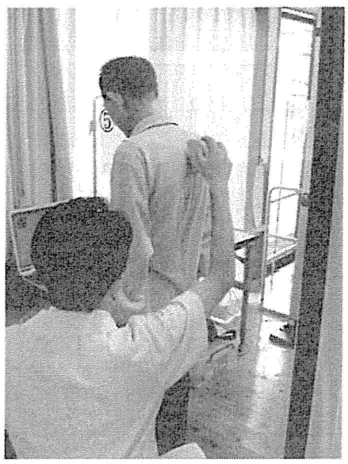
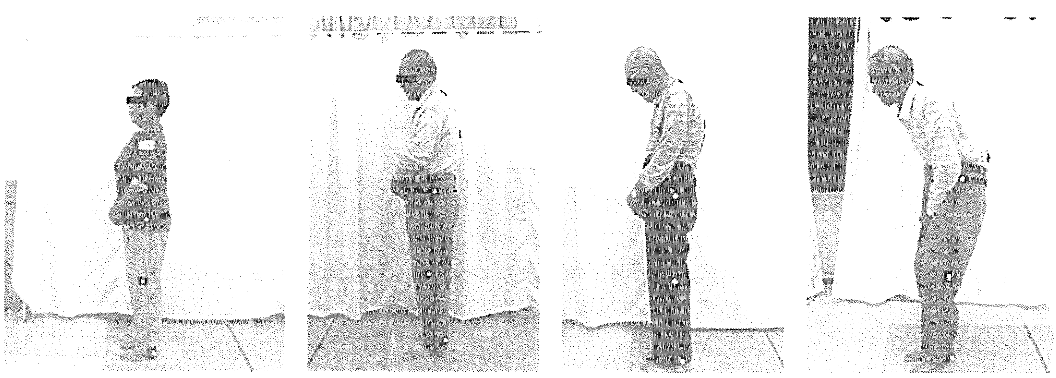


図 5　脊柱形状測定デバイスによる計測

4．外 観 評 価

脊柱姿勢の外観評価（見た目の評価）は，これまでにも多く行われている。Takahashi ら[5]は，地域の健診の場において計測可能な方法として，薄着のまま第7頚椎，第6胸椎，第4腰椎，大転子，大腿骨外側顆，外踝等にマーカーを装着し，写真により体幹姿勢を5つに分類する方法を提唱している。われわれはさらに計測法を簡略化し，必ずしも整形外科的な知識を有さない非専門家（地域の保健師）でも，見た目だけで脊柱の後弯姿勢を4段階に評価できる方法を試みた。時間的余裕がない現場での脊柱後弯者の簡易スクリーニングに利用可能かどうかを検証する目的である。ここでは，評価者は図6に提示したサンプル写真をもとに，65歳以上の561名の対象者を「1. 後弯なし」「2. 軽度後弯」「3. 2と4の中間」「4. 強度後弯」の4段階に分類した。分類3以上を後弯とした場合の妥当性（感度，特異度，陽性反応的中率，陰性反応的中率）を算出した。前述の後弯指数の



1：後弯なし　　2：軽度後弯　　3：2と4の中間　　4：強度後弯

図 6　簡易後弯評価法

サンプル写真では体表にマーカーを装着しているが，実際の判定時にはマーカーはつけていない。

表 1　Gold standard に対する簡易後弯評価（分類 3 以上を後弯とした場合）の妥当性

		Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)
Male	KI 20 percentile	51.0	86.9	50.0	87.4
	KI 10 percentile	64.0	84.0	30.8	95.5
	OTD 3 blocks	38.8	87.7	59.6	75.3
	OTD 4 blocks	48.5	83.4	30.8	91.4
Female	KI 20 percentile	74.6	76.9	45.2	92.2
	KI 10 percentile	**84.4**	**72.3**	26.0	97.6
	OTD 3 blocks	82.0	78.6	48.5	94.7
	OTD 4 blocks	**93.9**	**73.9**	30.1	99.0

上位 10 ないし 20%，および OTD で 3 ないし 4 ブロック以上を gold standard とした。結果を表 1 に示した。女性の後弯指数上位 10 percentile および OTD 4 以上の高度後弯検出の感度はそれぞれ 84%，94%，特異度は 72%，74%とおおむね良好であった。男性では感度不足であった。おそらく女性の方が高度後弯者が多く，簡易評価による誤分類が少なかったのが一因と思われた。

以上より，本法のような簡易評価法であっても，高度後弯のスクリーニングとしては十分な妥当性を有していると考えられ，地域保健の現場では考慮されてよいと考察した。

Ⅱ．脊柱後弯姿勢が ADL 障害に及ぼす影響

脊柱姿勢が，高齢者の自立した生活の維持に重要であることのエビデンスが集積しつつある。Hirose ら[6]は，脊柱後弯を含めた脊柱姿勢の異常は，歩行能力に対して影響を与え，ADL に多大な影響を与えると報告している。Kado ら[7]は，OTD で後弯を評価し，高度後弯変形と外傷を伴う転倒の関連を報告している。Ryan ら[4]は，occiput-to-wall distance で胸椎後弯を評価し，後弯変形が ADL 低下，特に移動能力の低下をもたらしていると述べている。また，Takahashi ら[5]は，脊柱変形がある群は正常群に比べて主観的健康観や満足度が低いと報告している。われわれの検討では，女性において後弯指数の増加は主観的な健康度低下と関連していたが，男性においてはこれらの関連は明らかでなかった[2]。

このように，脊柱姿勢，特にその後弯変形が ADL，QOL の低下と関連するとの報告が多くなされている。しかしながら，これらの大半は時間断面研究であり，関連の時間性を証明するのに困難がある。また，研究の多くはクリニカルベースのものであり，地域在住者を対象とした community-based なエビデンスが不足している。そこで，われわれのグループは，地域在住高齢者を対象として，OTD 法で測定した後弯が，将来の ADL と関連するかどうかを前向きコホート研究デザインにて検討した。

対象は，65 歳以上の地域在住高齢者で追跡開始時に ADL 低下のない 792 名（男 333，女 459）である。後弯の評価は OTD 法で行った。アウトカムとしては，4.5 年の追跡期間中の ADL 低下および死亡とした。ここで，ADL 低下とは，要介護・要支援状態の発生，Katz 基本 ADL の少なくとも 1 つの項目で半介助以上，施設入所のいずれかでもあれば ADL 低下と定義した。ロジスティック回帰分析により，年齢，性別，婚姻状態，教育歴，重大疾病の既往（脳卒中，心筋梗塞，狭心症，肺気腫，慢性気管支炎，糖尿病，がん），喫煙を調整した。結果として，OTD で 3 ブロック以上の脊柱後弯は，将来の複合アウトカム（ADL 低下＋死亡）の発生リスクを増加させた。0 ブロック（後弯なし）を基準とした場合の調整済みオッズ比(95% CI）は，1.86（1.05-3.30）であった（図 7）。個別

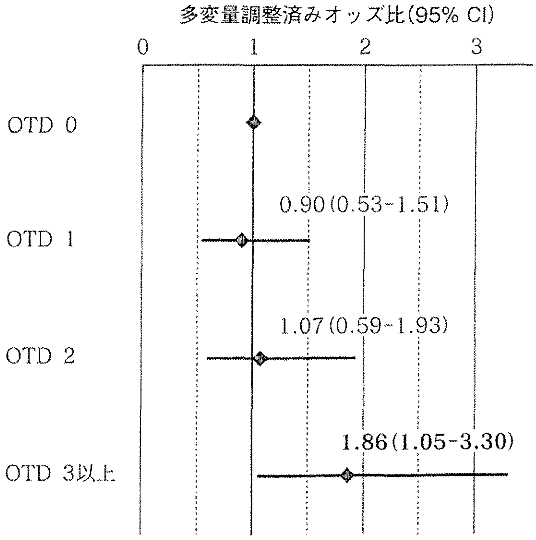


図 7 後弯と複合アウトカム（ADL 低下＋死亡）との関連

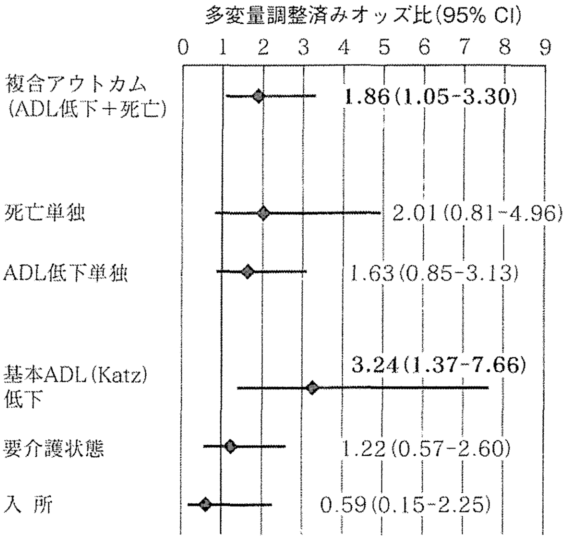


図 8 OTD 3 以上の後弯と個別アウトカム

のアウトカムに対する 3 ブロック以上の脊柱後弯の調整済みオッズ比は，図 8 のとおりで，Katz 基本 ADL 低下との間に統計学的に有意な関連を認めた (3.24 [1.37-7.66])。要介護状態とは有意な関連を示さなかったが，オッズ比は上昇しており，今後追跡期間の延長に伴いアウトカムイベントの発生が多くなってくると，統計学的に有意となる可能性がある。

Ⅲ．脊柱後弯姿勢が死亡に及ぼす影響

図 8 に示したとおり，われわれのデータでは，OTD 3 以上の後弯があると死亡のオッズが 2 倍となっていた。統計学的には有意ではないが，これも追跡の延長により有意になってくると推測される。米国の先行研究によれば，OTD で計測された後弯は，圧迫骨折や骨密度を調整しても，なお将来の死亡を予測していた[3]。特に動脈硬化関連の死亡との関連が示され，後弯は生理学的な加齢を反映するマーカーになり得ると筆者は考察している。後弯そのものを計測したわけではないが，加齢による身長の低下が将来の死亡と関連していたとの研究結果[8]もわが国から報告されており，興味深い。

Ⅳ．今後の課題

このように，脊柱の後弯姿勢は将来の ADL，QOL の低下のみならず，死亡とも関連している可能性が示唆される。そのメカニズムはまだ解明されていないが，上述の生理的な加齢の進行以外にも，体幹変形から惹起される心肺への物理的圧迫や，重心の前方移動から生じるバランス障害による転倒，骨折の増加などを介するメカニズムなどが想定され得る。いずれにせよ，後弯のある高齢者は frail（虚弱）な集団として認識すべきものと思われる。

介護予防の達成のためには，こうしたハイリスク集団の特定を地域保健の現場で行う必要がある。後弯の評価については文中に述べたとおり X 線を用いない計測法も複数あり，非専門家による判定でもそれなりにスクリーニングとしての妥当性を有していることから，クリニックのみならず地域保健現場での後弯者の抽出も可能と考えられる。こうした後弯者は積極的に地域の介護予防事業者の対象としていくことが求められるだろう。

しかしながら，後弯そのものが介入によって改善可能かどうかに関してはエビデンスがほとんどない。今後の課題といえるだろう。この場合，骨

性要素の回復は困難と思われるので，背筋の強化を中心とした介入が考えられる。

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整形外科用語の散歩道

国分正一

423. Osteoclasis 骨砕き術

日整会整形外科学用語集（第7版）によれば，osteoclasis の邦語訳は骨砕き術である。「骨砕き」からは，恐らく，整形外科医の殆んどがその術式を想像できまい。何故，そして何処の骨をどう砕くのか，と言った素朴な疑問を抱く筈である。

Osteoclasis は，例えば，小児骨幹端骨折の変形治癒に対し，凸側に楔状骨切りを加え，摘出した楔を細片にして戻す。凹側皮質に pin で幾つか穴を開けた後に閉創し，ギプスで固定する。肉芽・仮骨が形成の術後3週頃に，用手的に骨折させて矯正し，再度ギプス固定とする。内固定・創外固定の要らぬ手術である（JBJS **61-B**：410, 1979）。

Osteoclasis の clasis はギリシャ語の klaein 壊す，折る，砕くに起源がある。その過去分詞が klastos で，osteoclast 破骨細胞の由来がここにある。他方，名詞化したものが clasis である。術式の実際に沿えば，「骨砕き術」よりも「折骨術」ないし「破骨術」が妥当でなかろうか。

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Association of Knee Osteoarthritis with the Accumulation of Metabolic Risk Factors Such as Overweight, Hypertension, Dyslipidemia, and Impaired Glucose Tolerance in Japanese Men and Women: The ROAD Study

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ABSTRACT. ***Objective.*** To clarify the association of knee osteoarthritis (KOA) with overweight (OW), hypertension (HTN), dyslipidemia (DL), and impaired glucose tolerance (IGT), which are components of metabolic syndrome (MS), in a Japanese population.

Methods. We enrolled 1690 participants (596 men, 1094 women) from the large-scale cohort study Research on Osteoarthritis Against Disability (ROAD), begun in 2005 to clarify epidemiologic features of OA in Japan. KOA was evaluated by the Kellgren-Lawrence grade, minimum joint space width (MJSW), minimum joint space area (JSA), and osteophyte area (OPA). OW, HTN, DL, and IGT were assessed using standard criteria.

Results. The prevalence of KOA in the total population in the age groups ≤ 39, 40–49, 50–59, 60–69, 70–79, and ≥ 80 years was 2.2%, 10.7%, 28.2%, 50.8%, 69.0%, and 80.5%, respectively. Logistic regression analyses after adjustment for age, sex, regional difference, smoking habit, alcohol consumption, physical activities, regular exercise, and history of knee injuries revealed that the OR of KOA significantly increased according to the number of MS components present (1 component: OR 1.21, 95% CI 0.88–1.68, $p = 0.237$; 2 components: OR 1.89, 95% CI 1.33–2.70, $p < 0.001$; 3 or more components: OR 2.72, 95% CI 1.77–4.18; $p < 0.001$). The number of MS components was inversely related to medial MSJW ($ß = -0.148$, $R^2 = 0.21$, $p < 0.001$), medial JSA (women only; $ß = -0.096$, $R^2 = 0.18$, $p = 0.001$), and positively related to OPA ($ß = 0.12$, $R^2 = 0.11$, $p < 0.001$).

Conclusion. The accumulation of MS components is significantly related to presence of KOA. MS prevention may be useful to reduce cardiovascular disease and KOA risk. (First Release Feb 15 2011; J Rheumatol 2011;38:921–30; doi:10.3899/jrheum.100569)

Key Indexing Terms:
EPIDEMIOLOGY METABOLIC SYNDROME KNEE OSTEOARTHRITIS
RISK FACTORS ROAD STUDY

Osteoarthritis (OA), which causes cartilage and disc degeneration and osteophyte formation at joints in the limbs and spine, is a major public health problem in the elderly that affects activities of daily living (ADL) and quality of life, leading to increased morbidity and mortality[1,2,3]. According to the recent National Livelihood Survey by the Ministry of Health, Labour and Welfare in Japan, OA is ranked fourth among diseases that cause disabilities requiring support and longterm care[4].

In the same report, cardiovascular disease (CVD) is

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ranked first in causing disabilities in the elderly[4]. Most individuals who develop CVD have multiple risk factors[5]. The presence of these risk factors in specific combinations, called metabolic syndrome (MS), is a complex risk factor that predisposes affected individuals to CVD morbidity and mortality. Although various terms have been used to define MS, it is generally thought to consist of a combination of overweight (OW), hypertension (HTN), dyslipidemia (DL), and impaired glucose tolerance (IGT)[6].

Knee OA (KOA) and MS share age and obesity as risk factors[1,7,8,9,10,11]. Many investigators have considered the association of OA with other components of MS. In an early population study, Lawrence first reported that diastolic blood pressure was associated with KOA in women[12]. Regarding DL, Kellgren reported a significant association between women with hand OA and above-average serum cholesterol levels in the 1960s[13]. Cimmino and Cutolo examined the role of glucose and OA, and observed significantly higher levels of plasma glucose in women with OA than in those without OA[14]. Although contradictory findings regarding the association of such metabolic factors with OA have been reported[15,16,17,18,19], Hart, *et al* found that metabolic factors such as blood glucose, hypercholesterolemia, and even treated HTN were associated with the development of KOA. Based on that evidence, they proposed that the etiology of OA had an important systemic and metabolic component[20]. This hypothesis has been supported by data from several population-based studies performed in the United States[21,22]. However, to our knowledge, few population-based studies have demonstrated a dose-response relationship between the severity of KOA and an increasing number of the components of MS. Our first purpose was to clarify the association between the presence of KOA, defined using the Kellgren-Lawrence (KL) scale, and the number of MS components in a Japanese population.

Moreover, in most of these studies that confirmed the association between the presence of KOA and the components of MS, KOA was defined according to KL grade[23]. KL grade is the most conventional system for measuring the radiographic severity of KOA, but does not separately assess joint space narrowing and osteophyte formation. Accumulating evidence has shown that osteophytosis and joint space narrowing have distinct etiologic mechanisms, and their progression is neither constant nor proportional[24,25,26]. Thus, to examine the factors associated with KOA, these 2 OA features should be assessed separately. However, no reports to date have clarified the association of indices of KOA, such as minimum joint space width (MJSW), joint space area (JSA), and osteophyte area (OPA), with the accumulation of the number of components of MS. Our second purpose was to determine whether the accumulation of MS components influenced the values of MJSW, JSA, and OPA.

Further, MS is an emerging epidemic in both men and women worldwide, and with the increase in the global population of Asians, an understanding of the epidemiology of diseases as they relate to Asian populations is required. We have reported that the prevalence of KOA was much higher in a Japanese population than in elderly whites in the United States and Europe, although not largely different from that of African American and Chinese populations[27]. In contrast, the prevalence of MS in East Asian countries including China, Korea, and Japan was reported to be lower than in white populations[28]. In light of the rapid increase in the population of Asian countries, prevention strategies for obesity-related chronic diseases such as MS and KOA should be implemented immediately. Our final aim was to clarify the association between MA components and KOA in people of Asian ethnicity.

MATERIALS AND METHODS

Study population. We used the cohorts established in 2005 for a program called Research on Osteoarthritis Against Disability (ROAD). The ROAD study is a nationwide, prospective study of OA composed of population-based cohorts in several communities in Japan. Details of the cohort profile have been reported[29,30], thus the study population is described here only in brief. We created a baseline database including clinical and genetic information from 3040 residents of Japan (1061 men and 1979 women) with a mean age (SD) of 70.3 (11.0) years [71.0 (10.7) years in men and 69.9 (11.2) years in women]. These subjects were recruited from resident registration listings in 3 communities with different characteristics: an urban region in Itabashi, Tokyo; a mountainous region in Hidakagawa, Wakayama; and a coastal region in Taiji, Wakayama.

We enrolled 1690 Japanese subjects (596 men; 1094 women) residing in the mountainous and coastal areas. Table 1 lists the background characteristics of all the participants. All participants provided written informed consent, and the study was conducted with the approval of the ethics committees of the University of Tokyo. Participants completed an interviewer administered questionnaire of 400 items that included lifestyle information such as occupation, smoking habit, alcohol consumption, family history, medical history, physical activity, reproductive variables, and health-related quality of life. Anthropometric measurements included height, weight, waist length (seaside region only), wrist circumference, bilateral grip strength, and body mass index [BMI; weight (kg)/height (m)^2]. Systolic and diastolic blood pressure (BP) were measured by an experienced public health nurse using a mercury sphygmomanometer. Medical information on systemic, local, and mental health status, including information concerning knee, hip, and lower back pain; swelling and range of motion of the joints; and patellar and Achilles tendon reflex was collected by experienced orthopedic surgeons.

Radiographic assessment. All participants underwent radiographic examination of both knees using an anterior-posterior view with weight-bearing and foot-map positioning. Fluoroscopic guidance with a horizontal anterior-posterior radiograph beam was used to visualize the joint space. Knee radiographs were read by a single experienced orthopedist without knowledge of participants' clinical status, and categorized using the KL grading scale[23]. Regarding the differences in knee OA grades between the 2 sides, among 1681 participants who underwent X-ray examinations of both knees, 1226 (72.9%) individuals had the same KL grades for both knees. For 396 (23.6%) participants, the difference in knee KL grades between the 2 knees was 1, and for the remaining 59 (3.5%) subjects, the KL grades differed by more than 2 grades. In such cases, the higher KL grade was assigned to the participant. The same observer scored 100 randomly selected knee radiographs more than 1 month after the first reading to determine intraobserver variability. The intraobserver variability (0.86) evaluated for KL grade (0–4) was confirmed by kappa analysis to be sufficient for the assessment.

Table 1. Background characteristics of the participants.

	Total	Men	Women
Age, yrs			
≤ 39	45	14	31
40–49	149	44	105
50–59	316	107	209
60–69	482	157	325
70–79	539	220	319
≥ 80	159	54	105
Total, n	1690	596	1094
Mean (SD) selected characteristics			
Age, yrs	65.2 (12.0)	66.3 (11.7)	64.7 (12.1)
Height, cm	155.2 (9.3)	163.4 (7.2)	150.7 (6.9)
Weight, kg	55.6 (10.8)	62.2 (10.9)	52.0 (8.8)
BMI, kg/m^2	23.0 (3.4)	23.2 (3.2)	22.9 (3.5)
Systolic BP, mm Hg	135.1 (20.7)	137.9 (19.6)	133.5 (21.1)
Diastolic BP, mm Hg	74.2 (11.5)	77.0 (11.6)	72.7 (11.2)
Serum levels of HDL cholesterol, mg/dl	60.8 (15.7)	56.1 (15.8)	63.4 (15.0)
Serum levels of HbA1c, %	5.20 (0.74)	5.23 (0.83)	5.19 (0.68)
Prevalence of selected characteristics, %			
Current smoking habit	13.1	29.9	3.8
Current alcohol consumption	39.8	66.7	25.1
Medication for hypertension	32.3	29.5	33.9
Medication for dyslipidemia	6.5	3.0	8.5
Medication for diabetes mellitus (including insulin injection)	5.9	7.7	4.9
Prevalence of each component of metabolic syndrome, %			
Obesity	25.3	26.7	24.6
Hypertension	69.7	74.8	66.9
Dyslipidemia	12.3	13.9	11.4
Impaired glucose tolerance	21.5	24.3	20.0

BMI: body mass index; BP: blood pressure; HDL: high-density lipoprotein; HbA1c: hemoglobin A1c.

Further, to evaluate the KOA severity using quantitative measurements, the medial and lateral MJSW, medial and lateral JSA, and OPA were measured separately, using a KOA computer-assisted diagnostic system (KOACAD). The KOACAD was programmed to measure MJSW and JSA in the medial and lateral compartments, OPA at the medial tibia, and femorotibial angle (FTA) using digitized knee radiographs. Initially, correction for radiographic magnification was performed on the basis of the image size of a rectangular metal plate.

Next, to determine the region of interest (ROI) including the tibiofemoral joint space, a vertical neighborhood difference filter was applied to identify points with high absolute values for difference of scales. The centers of all points were then calculated, and the ROI was selected. Within the ROI, the outline of the femoral condyle was designated as the upper rim of the joint space. The 2 ends were determined, and vertical lines from the ends were designated as the outside rims of the joint space. Outlines of the anterior and posterior margins of the tibial plateau were drawn similarly to that of the femoral condyle, and the middle line between the 2 outlines was designated as the lower rim of the joint space. A straight regression line for the lower rim outline was then drawn, and the intersection of the lower rim outline and the regression line were designated as the inside rims. Medial and lateral JSA were determined as areas surrounded by the upper, lower, inside, and outside rims. Medial and lateral MJSW were further determined as the minimum vertical distances in the respective JSA. To measure osteophyte area and FTA, medial and lateral outlines of the femur and tibia were drawn. Inflection points for these outlines were then calculated. The medial outline of the tibia from the inflection point was drawn upward to the joint level, and the area that was medially prominent over the smoothly extended outline was designated as the osteophyte area. For FTA, a middle line between the medial and lateral outlines of the femur from the top of the image to the inflection points was drawn, and the straight regression line was determined as the axis of the femur. Similarly, the straight regression line of the middle line of the tibia from the bottom to the inflection points was designated as the axis of the tibia. The lateral angle between the 2 axes lines was calculated as FTA. In general clinical practice, this system can quantify the major features of knee OA on standard radiographs and allows objective, accurate, simple, and easy assessment of the structural severity of knee OA without any manual operation.

Regarding the relationship between the measurements of KOA, we have confirmed the correlation values were more than 0.5 between medial JSA and medial MJSW, and between lateral JSA and lateral MJSW, indicating that these are confounding factors for each other. Osteophyte area was not significantly associated with either medial JSA or medial MJSW. Further, JSA and MJSW on the lateral side were positively correlated with those on the medial side. These measurements showed good correlation between KL grades ($p < 0.0001$)[31].

Blood examination. All blood and urine samples were extracted between 9:00 AM and 3:00 PM. Some samples were extracted under fasting conditions. After centrifugation of blood samples, sera were immediately placed in dry ice and transferred to a deep freezer within 24 hours. These samples were stored at –80°C until assayed.

For the samples of participants in the baseline study, the following items were measured: blood counts, hemoglobin, hemoglobin A1c (HbA1c), blood sugar, total protein, aspartate aminotransferase, alanine aminotransferase, γ-glutamyltranspeptidase, high-density lipoprotein (HDL) cholesterol, total cholesterol, triglycerides (TG), blood urea nitrogen, uric acid, and creatinine. These analyses were performed at the same laboratory within 24 hours after the extraction (Osaka Kessei Research Laboratories Inc., Osaka, Japan).

Definition of MS components. This definition was based mainly on the criteria of the Examination Committee of Criteria for Metabolic Syndrome in Japan[32]. According to these criteria, an abdominal circumference ≥ 85 cm in men and ≥ 90 cm in women is a necessary condition for MS. HTN was diagnosed as systolic BP ≥ 130 mm Hg and/or diastolic BP ≥ 85 mm Hg, DL as serum TG level ≥ 150 mg/dl and/or serum HDL cholesterol level < 40 mg/dl, and IGT as fasting serum glucose ≥ 110 mg/dl. Because there has been considerable debate regarding the measurement of abdominal circumference[33,34], we decided to use BMI ≥ 25 instead as an indicator of overweight, based on the criteria of the Japan Society for the Study of Obesity[33]. Also, because not all blood samples were obtained under fasting conditions, we did not use participants' data concerning serum levels of glucose and TG, because of their large variation depending on hours after eating. Instead, we used a serum HDL cholesterol level < 40 mg/dl to indicate DL, and serum HbA1c level ≥ 5.5% to indicate IGT. These are indices used in the National Health and Nutrition Survey in Japan, and they were adopted as criteria for MS in this national screening based on the difficulty of collecting the samples under fasting conditions[35]. Further, subjects being treated with medication for HTN, DL, or diabetes mellitus were regarded as having the respective disorder.

Statistical analysis. All statistical analyses were performed using Stata statistical software (Stata Corp., College Station, TX, USA). Differences in proportion were compared by the chi-squared test. Differences in continuous values were tested for significance using ANOVA for comparisons among multiple groups, and Scheffe's least significant difference test for pairs of groups. Significant items were selected, and multiple regression and logistic regression analyses were performed by adjusting selected variables. Various confounding factors were used for the adjustment for each multivariate analysis.

RESULTS

Study population. Table 1 shows selected characteristics of the participants including age, height, weight, BMI, systolic