Clinical Section / Original Paper

Gerontology

Gerontology
DOI: 10.1159/000336988

Received: December 5, 2011
Accepted after revision: January 31, 2012
Published online: April 6, 2012

A Lower Prevalence of Self-Reported Fear of Falling Is Associated with Memory Decline among Older Adults

Kazuki Uemura[a] Hiroyuki Shimada[a] Hyuma Makizako[a] Daisuke Yoshida[a] Takehiko Doi[a] Kota Tsutsumimoto[a] Takao Suzuki[b]

[a]Section for Health Promotion, Department of Health and Medical Care, Center for Development of Advanced Medicine for Dementia, National Center for Geriatrics and Gerontology, and [b]Research Institute, National Center for Geriatrics and Gerontology, Obu, Japan

Key Words
Elderly · Fear of falling · Memory · Falls · Cognitive decline

Abstract
Background: In spite of a number of reports about various factors associated with the fear of falling (FoF) among older adults (such as age and physical function), the relationship between FoF and cognitive decline remains unclear. ***Objective:*** To determine which cognitive function is related with the prevalence of FoF in older adults. ***Methods:*** Participants were 101 older adults (mean age 75.1 years; 48.5% males). Of these, 54 older adults (53.4%) were classified as the fear group on the basis of the presence of FoF. Age, gender, the Timed Up and Go test (TUG), fall history, the Alzheimer's Disease Assessment Scale, the Wechsler Memory Scale-Revised-Logical Memory I (WMS-LM I), the delayed memory test, digit symbol coding, digit span and verbal fluency were measured as potential relevant factors. ***Results:*** Logistic regression analysis revealed that TUG [odds ratio (OR) 1.43, 95% confidence interval (CI) 1.12–1.83; p = 0.004], WMS-LM I (OR 1.20, 95% CI 1.07–1.35; p = 0.002) and fall history (OR 4.38, 95% CI 1.53–12.51; p = 0.006) were independently associated with FoF. ***Conclusions:*** The results suggest that a lower prevalence of self-reported FoF is associated with memory decline among older adults. Insensitivity to FoF may be one of the characteristics of psychological change with memory decline.

Introduction

Fear of falling (FoF) refers to a lack of self-confidence that normal activities can be performed without falling [1]. Other authors define FoF as a general concept that describes low fall-related efficacy (low confidence in avoiding falls) and being afraid of falling [2]. The prevalence of FoF ranges from 33 to 40%, is higher in women and increases with age [3, 4]. FoF is associated with poor health status [2, 5], functional decline [6, 7], psychological problems [8, 9] and restriction of activities [4, 10]. It is considered important to reduce FoF by targeting down-

K.U. and H.M. are Research Fellows of the Japan Society for the Promotion of Science.

KARGER

Fax +41 61 306 12 34
E-Mail karger@karger.ch
www.karger.com

0304–324X/12/0000–0000$38.00/0

Accessible online at:
www.karger.com/ger

Kazuki Uemura, MSc
Section for Health Promotion, Department of Health and Medical Care
Center for Development of Advanced Medicine for Dementia, National Center for Geriatrics and Gerontology, 35 Gengo Morioka, Obu, Aichi 474-8511 (Japan)
Tel. +81 562 44 5651, E-Mail uemura@ncgg.go.jp

stream factors, such as increasing physical functioning [11]. In spite of a number of reports about various factors associated with FoF, there is no literature examining the relationship between FoF and cognitive functions that inevitably decline with age.

Several aspects of age-related decline of cognitive function are well documented and contribute to the deterioration of the ability to carry out tasks in activities of daily living. For example, memory difficulty is related to slower performance of timed instrumental activities of daily living tasks [12]. Additionally, cognitive impairment is one of the key factors contributing to accidental falls [13]. Recent evidence indicates that even mild cognitive decline is a risk factor for falls [14]. In seniors with Mini-Mental State Examination (MMSE) scores greater than 24 out of 30, baseline cognitive performance was found to be linearly and inversely associated with the rate of falling over 8 years [14]. Within the multiple domains of cognitive function, impaired executive function and memory decline are predictive of accidental falls in older adults [14–16] and are prevalent even in healthy, community-dwelling seniors without dementia (MMSE score >24) [17, 18]. FoF has been recognized as an important psychological factor associated with accidental falls and restricting everyday functioning [19–21]. In addition to studying the risk of falling, investigation of FoF may also be key to the medical management of older adults with mild cognitive decline. Cognitive function includes several domains, such as general, memory, processing speed, language and executive function. However, no previous studies have reported which cognitive declines contribute to the experience of FoF in older adults.

The purpose of this study is to determine the relationship between FoF and potential correlates in older adults with cognitive decline and to identify which cognitive declines are associated with FoF. This investigation is critical to the exploration of psychological factors associated with accidental falls and restricting everyday functioning, enabling the planning of future rehabilitation programs that prevent falls and maintain activities in older adults with cognitive decline.

Methods

Participants

The participants were recruited from two volunteer databases (n = 1,543), which included elderly participants aged 65 years and over who were selected by random sampling or attended a health check in Obu. In the first eligibility assessment for this study, 528 potential participants were enrolled. One hundred and sixty-five participants responded to the second eligibility assessment, and 108 participants completed the assessment and met the inclusion criteria. The inclusion criteria were that they had to be living independently in the community, Japanese-speaking and able to participate in the examinations, and they had to have adequate hearing and visual acuity. In addition, general cognitive function was found to be intact in all 108 participants, whose MMSE scores were in the range of 24–30 [22]. Seven participants were excluded based on the following exclusion criteria: a history of major psychiatric illness, other serious neurological or musculoskeletal diagnoses or depression (Geriatric Depression Scale score ≥10 [23]). The final sample used for analysis consisted of 101 older adults (mean age 75.1 years; 48.5% males; mean educational history 10.7 years). This study was approved by the ethics committee of the National Center for Geriatrics and Gerontology. All participants provided written informed consent.

Measurements

Demographic data were recorded, including age, gender, educational history and number of medications. FoF was assessed by a fourth-ordered choice, closed-ended question about participants' general FoF. The question was phrased as follows: 'Are you afraid of falling?' Participants who responded 'very much' or 'somewhat' were assigned to the fear group; participants who responded 'a little' or 'not at all' were assigned to the no-fear group [24] , which had a high test-retest reliability of up to 0.9 in a sample of 44 randomly selected individuals [25].

The participants also completed a standardized questionnaire that recorded the number of times they had fallen in the past year. A fall was defined as an event where a person unintentionally comes to rest on the ground, floor or another lower level [26]. Falls resulting from extraordinary environmental factors (e.g. traffic accidents or falls while riding a bicycle) were excluded from the count. On the basis of their fall history, participants were divided into two groups, namely fallers (1 or more falls) and nonfallers (0 falls).

The participants underwent 3 clinical measurements to assess physical performance, namely the Timed Up and Go Test (TUG), the one-leg standing test and the 5-meter walking test, in the presence of an experienced physiotherapist. The TUG [27] involves rising from a chair, walking 3 m, turning around, walking back to the chair and sitting down. Participants were instructed to complete the task at their usual pace. The score represented the time in seconds that the participant needed to complete the assessment. Less time taken to accomplish this task indicated better balancing and gait ability. The shorter time measured in the two trials was recorded as the TUG score. In the one-leg standing test, the participants were asked to stand on their preferred leg as long as possible with their arms hanging down and with eyes open. One-leg standing balance was measured as the time (0–120 s) participants could stand on one leg. The longer time measured in the two trials was recorded as the one-leg standing test score. In the 5-meter walking test, participants were asked to walk along a straight, level path at their 'normal walking speed'. Walking time was calculated using a stopwatch to measure the time taken to cover the central 5 m of the walkway (2 m at the start and finish were used for acceleration and deceleration). The walking time score was calculated as the shorter time in seconds for completion of two trials.

All neuropsychological tests were conducted by well-trained speech therapists, and each score was rechecked by a single speech

Table 1. Demographic and clinical characteristics of study participants

	Fear group (n = 54)	No-fear group (n = 47)	p value	Effect size
Age, years	76.2 ± 6.8 (65–93)	73.7 ± 6.7 (69–94)	0.071	0.37
Education, years	10.5 ± 2.2	11.0 ± 2.8	0.251	0.20
Males	20 (37.0)	29 (61.7)	0.013	0.25
Number of medications	2.8 ± 2.2	2.0 ± 2.3	0.087	0.36
GDS score	3.3 ± 2.4	2.7 ± 2.2	0.232	0.26
Fall history	21 (38.9)	9 (19.1)	0.030	0.22
TUG, s	9.7 ± 2.6	8.5 ± 2.1	0.013	0.51
One-leg standing test, s	31.3 ± 23.7	41.1 ± 23.2	0.041	0.42
5-Meter walking time, s	5.0 ± 1.8	4.6 ± 1.1	0.12	0.27

Values are means ± SD (range) or numbers of participants (%). GDS = Geriatric Depression Scale. Effect sizes are based on Cohen's d (t test) or ϕ (χ^2).

therapist who was blinded to the other data of the participants in this study. General cognitive function was evaluated using the Alzheimer's Disease Assessment Scale (ADAS) [28]. The ADAS was designed specifically to evaluate cognitive and behavioral dysfunctions characteristic of Alzheimer's disease. On this test, the scores range from 0 to 70 points, with fewer points indicating a better score.

Memory function was evaluated by the Logical Memory I (story A only) from the Japanese version of the Wechsler Memory Scale-Revised (WMS-LM I) [29]. On this task, a short story that consisted of 25 segments was read aloud to the participant, who was instructed to recall details of the story immediately. On this test, the scores ranged from 0 to 25 points, with more points indicating a better score. The delayed memory test was also conducted, which is a three-word recall test in the MMSE [22]. In this study, delayed memory was converted to categorical variables, i.e. 0 (1 or more mistakes with the three words) or 1 point (all three words correct).

Processing speed was assessed by using a version of the digit symbol coding subtest of the Wechsler Adult Intelligence Scale III [30]. In the test, participants copied symbols that are paired with numbers. Using the key provided at the top of the exercise form, the participant drew the symbol under the corresponding number. The score for digit symbol coding was the number of correct symbols drawn within 120 s. One point is given for each correctly drawn symbol completed within the time limit, for a maximum score of 133.

Executive function was assessed using the Trail Making Test, part B [31]. Participants were required to navigate a series of alternating numbers and letters and connect them in alternating sequential order. The time required to complete each task was recorded, with more time indicating worse performance.

We also conducted a digit span forward test and a digit span backward test. Both tests are a subset of the Wechsler Adult Intelligence Scale III [30] and require participants to repeat a series of verbally presented digits of increasing length in forward and backward order. Performance on the digit span task strongly depended upon working memory, cognitive regulation and manipulation, all of which are components of executive function. The score recorded, ranging from 0 to 14, was the number of successful sequences.

Verbal fluency is composed of letter fluency and category fluency [32]. The participants were asked to generate as many words as possible within 1 min, consisting of an initial letter (letter fluency) and an animal name (category fluency) [33]. Verbal fluency is an evaluation of expressive language ability and executive function [32–34]. The score was the number of successful words (except for some proper nouns).

Statistical Analysis

Unpaired t tests or χ^2 tests (for gender, fall history and delayed memory) were used to evaluate the differences in measurements between the fear and no-fear groups. Cohen's d (t test) or ϕ (χ^2) values were calculated as measures of effect size.

Logistic regression analysis, performed as a stepwise analysis, was carried out to examine whether the potential determinants were independently associated with FoF. In this analysis, the presence or absence of FoF was used as the dependent variable (no-fear = 0, fear = 1), and age and variables that showed a significant difference between the fear and no-fear groups were employed as independent variables. Gender and fall history were created as categorical variables (male = 0, female = 1; nonfaller = 0, faller = 1). Statistical analyses were conducted using software package SPSS version 11.0 (SPSS Inc., Chicago, Ill., USA), and $p < 0.05$ was accepted as significant.

Results

Fifty-four older adults out of 101 participants (53.4%) were classified into the fear group, and 47 older adults (46.6%) were classified into the no-fear group. Table 1 shows the differences in demographic variables and physical performance test scores between the fear and no-fear groups. There were no significant differences in age, educational history or number of medications. The fear group had a lower number of males than the no-fear group (fear group 37.0%, no-fear group 61.7%; $p = 0.013$),

Table 2. Cognitive characteristics of study participants

	Fear group (n = 54)	No-fear group (n = 47)	p value	Effect size
MMSE score	26.9 ± 2.2	27.2 ± 1.6	0.565	0.16
ADAS score	6.0 ± 3.5	6.2 ± 2.5	0.853	0.07
WMS-LM I score	8.5 ± 4.3	6.6 ± 4.6	0.033	0.43
Score of 1 on the delayed memory test	35 (64.8)	20 (42.6)	0.029	0.22
TMT-B, s	192.6 ± 82.9	180.6 ± 118	0.573	0.12
Digit symbol coding score	46.1 ± 15.2	48.1 ± 16.2	0.526	0.13
Digit span forward score	4.9 ± 0.1	4.9 ± 0.3	0.063	0
Digit span backward score	4.5 ± 0.8	4.5 ± 0.7	0.851	0
Letter fluency score	5.3 ± 3.1	6.1 ± 3.7	0.270	0.24
Category fluency score	15.1 ± 4.9	14.7 ± 4.4	0.691	0.09

Values are means ± SD or numbers of participants (%). TMT-B = Trail Making Test, part B. Effect sizes are based on Cohen's d (t test) or ϕ (χ^2).

while the number of fallers among the fear group was significantly higher than among the no-fear group (fear group 38.9%, no-fear group 19.1%; p = 0.03). With regard to physical performance tests, the fear group exhibited better scores on the TUG (p = 0.013) and one-leg standing test (p = 0.041) than the no-fear group. There were no significant differences in 5-meter walking time (p = 0.12).

Among several domains of cognitive function, only memory function showed significant differences between the groups. The fear group had significantly more points on the WMS-LM I (p = 0.033) than the no-fear group. More participants in the fear group than in the no-fear group scored 1 point on the delayed memory test (p = 0.029). There were no statistically significant differences in the MMSE, ADAS, digit symbol coding subtest, Trail Making Test, part B, digit span forward test, digit span backward test, letter fluency and category fluency between the groups (table 2).

Age, gender, fall history, TUG, WMS-LM I and delayed memory were entered into a stepwise logistic regression model. Logistic regression analysis revealed that TUG [odds ratio (OR) 1.43, 95% confidence interval (CI) 1.12–1.83; p = 0.004], WMS-LM I (OR 1.20, 95% CI 1.07–1.35; p = 0.002) and fall history (OR 4.38, 95% CI 1.53–12.51; p = 0.006) were independently associated with FoF, accounting for age and gender. Age, gender and delayed memory did not show a statistically significant relationship (table 3). The model was well calibrated between declines of observed and expected risk (Hosmer-Lemeshow χ^2 = 5.4, p = 0.72).

Table 3. Factors associated with FoF in stepwise logistic regression

Factor	OR	95% CI	p value
TUG	1.43	1.12–1.83	0.004
WMS-LM I	1.20	1.07–1.35	0.002
Fall history	4.38	1.53–12.51	0.006
Age	–	–	0.32
Gender	–	–	0.13
Delayed memory test	–	–	0.16
One-leg standing test	–	–	0.27

Discussion

This is the first study to clarify the relationship between cognitive decline and experience of FoF. It is in line with studies that show the prevalence of FoF is higher in females and in individuals with worse physical function (i.e. worse scores on the TUG and one-leg standing tests) and a history of falls [25, 35]. The results of the present study revealed that memory function was also significantly associated with FoF, which indicates that a lower prevalence of FoF is associated with memory decline among older adults, although there were no significant associations between FoF and other cognitive functions (i.e. general, processing speed, language and executive function). Interestingly, it can be suggested that worse physical function is likely to cause FoF, while worse memory function is likely to inhibit FoF in older adults.

Among the various cognitive functions, memory decline may influence FoF specifically. It might be difficult for nondemented participants with memory decline to recall detailed images of accidental falls. Memory decline is the initial symptom of dementia. Older adults with even very mild dementia are inclined to underestimate their functional deficits and have poor insight into depressive symptoms and behavioral changes, which is regarded as 'anosognosia' [36]. In the present study, it is possible that participants with memory decline may also have underestimated functional deficits, the risk of accidental falls and 'post-fall syndrome', which may lead to insensitivity to FoF. We considered that insensitivity to FoF may be one of the characteristics of psychological changes in older adults with memory decline.

Low prevalence of FoF might reduce the effect of rehabilitation programs on fall prevention and the maintenance of activities in older adults with memory decline. It was reported that multimedia patient education to prevent falls was not effective for patients with impaired cognitive function, although the same education reduced falls among patients with intact cognitive function [37]. These authors suggested that cognitive impairment can limit the ability of patients to adhere to planned safety-promoting behaviors. Arai et al. [38] reported that exercise intervention for physical function outcome might be beneficial to older adults with lower confidence for performing various activities without falling compared with those with higher confidence. It is possible that FoF in a way contributes to safety-promoting behaviors and adherence to exercise intervention. Therefore, insensitivity to FoF may be one of the factors reducing the effect of education and exercise intervention to prevent falls. It is possible that education and an exercise program specifically designed to address their cognitive needs and insensitivity to FoF is more beneficial for preventing falls among participants with memory decline.

This study has several limitations. Firstly, the sample size was relatively small. Secondly, as with other cross-sectional studies, the design of the current study limits the interpretation of the results with regard to causality between memory decline and FoF. A longitudinal study will be necessary to examine the causal relationship between memory decline, future fall incidence and expression of FoF. Thirdly, we did not collect data on certain factors that may influence FoF, such as perception of health [4] and emotional support [39]. These and other factors should be examined in future FoF studies.

In conclusion, memory decline is a specific aspect of cognition influencing experience of FoF in addition to physical function and fall history. The major implication of this study is that FoF was not only associated with worse physical performance but also memory function, which indicates that a lower prevalence of FoF is associated with memory decline among older adults. Insensitivity to FoF may be one of the characteristics of psychological change in older adults with memory decline. Future research is needed to clarify the causal relationship between memory decline, future fall incidence and expression of FoF.

Acknowledgments

We would like to thank the Obu city office for the help provided with regard to participant recruitment and the speech therapists of the Ukai rehabilitation hospital for their assistance with data collection.

Disclosure Statement

This work was supported by a grant from the Japanese Ministry of Health, Labor and Welfare (programs minimizing long-term care B-3, to T.S.).

References

1 Tinetti ME, Richman D, Powell L: Falls efficacy as a measure of fear of falling. J Gerontol 1990;45:P239–P243.
2 Cumming RG, Salkeld G, Thomas M, Szonyi G: Prospective study of the impact of fear of falling on activities of daily living, SF-36 scores, and nursing home admission. J Gerontol A Biol Sci Med Sci 2000;55:M299–M305.
3 Austin N, Devine A, Dick I, Prince R, Bruce D: Fear of falling in older women: a longitudinal study of incidence, persistence, and predictors. J Am Geriatr Soc 2007;55:1598–1603.
4 Zijlstra GA, van Haastregt JC, van Eijk JT, van Rossum E, Stalenhoef PA, Kempen GI: Prevalence and correlates of fear of falling, and associated avoidance of activity in the general population of community-living older people. Age Ageing 2007;36:304–309.
5 Howland J, Peterson EW, Levin WC, Fried L, Pordon D, Bak S: Fear of falling among the community-dwelling elderly. J Aging Health 1993;5:229–243.
6 Arfken CL, Lach HW, Birge SJ, Miller JP: The prevalence and correlates of fear of falling in elderly persons living in the community. Am J Public Health 1994;84:565–570.

7 Petrella RJ, Payne M, Myers A, Overend T, Chesworth B: Physical function and fear of falling after hip fracture rehabilitation in the elderly. Am J Phys Med Rehabil 2000;79: 154–160.
8 Lawrence RH, Tennstedt SL, Kasten LE, Shih J, Howland J, Jette AM: Intensity and correlates of fear of falling and hurting oneself in the next year: baseline findings from a Roybal Center fear of falling intervention. J Aging Health 1998;10:267–286.
9 Vellas BJ, Wayne SJ, Romero LJ, Baumgartner RN, Garry PJ: Fear of falling and restriction of mobility in elderly fallers. Age Ageing 1997;26:189–193.
10 Howland J, Lachman ME, Peterson EW, Cote J, Kasten L, Jette A: Covariates of fear of falling and associated activity curtailment. Gerontologist 1998;38:549–555.
11 Delbaere K, Crombez G, Vanderstraeten G, Willems T, Cambier D: Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. Age Ageing 2004;33:368–373.
12 Owsley C, Sloane M, McGwin G Jr, Ball K: Timed instrumental activities of daily living tasks: relationship to cognitive function and everyday performance assessments in older adults. Gerontology 2002;48:254–265.
13 Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. J Am Geriatr Soc 2001;49:664–672.
14 Anstey KJ, von Sanden C, Luszcz MA: An 8-year prospective study of the relationship between cognitive performance and falling in very old adults. J Am Geriatr Soc 2006;54: 1169–1176.
15 Nevitt MC, Cummings SR, Hudes ES: Risk factors for injurious falls: a prospective study. J Gerontol 1991;46:M164–M170.
16 van Schoor NM, Smit JH, Pluijm SM, Jonker C, Lips P: Different cognitive functions in relation to falls among older persons. Immediate memory as an independent risk factor for falls. J Clin Epidemiol 2002;55:855–862.
17 Gauthier S, Reisberg B, Zaudig M, Petersen RC, Ritchie K, Broich K, Belleville S, Brodaty H, Bennett D, Chertkow H, Cummings JL, de Leon M, Feldman H, Ganguli M, Hampel H, Scheltens P, Tierney MC, Whitehouse P, Winblad B: Mild cognitive impairment. Lancet 2006;367:1262–1270.
18 Royall DR, Cabello M, Polk MJ: Executive dyscontrol: an important factor affecting the level of care received by older retirees. J Am Geriatr Soc 1998;46:1519–1524.
19 Delbaere K, Close JC, Brodaty H, Sachdev P, Lord SR: Determinants of disparities between perceived and physiological risk of falling among elderly people: cohort study. BMJ 2010;341:c4165.
20 Deshpande N, Metter EJ, Lauretani F, Bandinelli S, Guralnik J, Ferrucci L: Activity restriction induced by fear of falling and objective and subjective measures of physical function: a prospective cohort study. J Am Geriatr Soc 2008;56:615–620.
21 Gagnon N, Flint AJ, Naglie G, Devins GM: Affective correlates of fear of falling in elderly persons. Am J Geriatr Psychiatry 2005;13: 7–14.
22 Folstein MF, Folstein SE, McHugh PR: 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198.
23 Yesavage JA: Geriatric depression scale. Psychopharmacol Bull 1988;24:709–711.
24 Maki BE, Holliday PJ, Topper AK: Fear of falling and postural performance in the elderly. J Gerontol 1991;46:M123–M131.
25 Chu CL, Liang CK, Chow PC, Lin YT, Tang KY, Chou MY, Chen LK, Lu T, Pan CC: Fear of falling (FF): psychosocial and physical factors among institutionalized older Chinese men in Taiwan. Arch Gerontol Geriatr 2011; 53:e232–e236.
26 Koski K, Luukinen H, Laippala P, Kivela SL: Physiological factors and medications as predictors of injurious falls by elderly people: a prospective population-based study. Age Ageing 1996;25:29–38.
27 Podsiadlo D, Richardson S: The timed 'up & go': a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39: 142–148.
28 Rosen WG, Mohs RC, Davis KL: A new rating scale for Alzheimer's disease. Am J Psychiatry 1984;141:1356–1364.
29 Wechsler D: Wechsler Memory Scale – Revised Manual. San Antonio, The Psychological Corporation, 1987.
30 Wechsler D: Wechsler Adult Intelligence Scale – III. San Antonio, The Psychological Corporation, 1997.
31 Kortte KB, Horner MD, Windham WK: The trail making test, part B: cognitive flexibility or ability to maintain set? Appl Neuropsychol 2002;9:106–109.
32 Benton AL: Differential behavioral effects in frontal lobe disease. Neuropsychologia 1968; 6:53–60.
33 Nemoto T, Kashima H, Mizuno M: Contribution of divergent thinking to community functioning in schizophrenia. Prog Neuropsychopharmacol Biol Psychiatry 2007;31: 517–524.
34 Lezak MD: Neuropsychological Assessment, ed 4. New York, Oxford University Press, 2004.
35 Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE: Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. Age Ageing 2008;37:19–24.
36 Starkstein SE, Jorge R, Mizrahi R, Robinson RG: A diagnostic formulation for anosognosia in Alzheimer's disease. J Neurol Neurosurg Psychiatry 2006;77:719–725.
37 Haines TP, Hill AM, Hill KD, McPhail S, Oliver D, Brauer S, Hoffmann T, Beer C: Patient education to prevent falls among older hospital inpatients: a randomized controlled trial. Arch Intern Med 2011;171:516–524.
38 Arai T, Obuchi S, Inaba Y, Nagasawa H, Shiba Y, Watanabe S, Kimura K, Kojima M: The effects of short-term exercise intervention on falls self-efficacy and the relationship between changes in physical function and falls self-efficacy in Japanese older people: a randomized controlled trial. Am J Phys Med Rehabil 2007;86:133–141.
39 Murphy SL, Williams CS, Gill TM: Characteristics associated with fear of falling and activity restriction in community-living older persons. J Am Geriatr Soc 2002;50:516–520.

Journals of Gerontology: MEDICAL SCIENCES
Cite journal as: J Gerontol A Biol Sci Med Sci
doi:10.1093/gerona/gls253

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

Kojiro Kamitani,[1,2] Takehiro Michikawa,[3] Satoko Iwasawa,[4] Norihito Eto,[5] Taichiro Tanaka,[1] Toru Takebayashi,[4] and Yuji Nishiwaki[1]

[1]Department of Environmental and Occupational Health, School of Medicine, Toho University, Tokyo, Japan.
[2]Department of Orthopedics, Ota General Hospital, Kanagawa, Japan.
[3]Environmental Epidemiology Section, Center for Environmental Health Sciences, National Institute for Environmental Studies, Tsukuba, Japan.
[4]Department of Preventive Medicine and Public Health, School of Medicine, Keio University, Tokyo, Japan.
[5]Department of Biomedical Engineering, School of Engineering, Tokai University, Kanagawa, Japan.

Address correspondence to Yuji Nishiwaki, MD, MSc, PhD, Department of Environmental and Occupational Health, School of Medicine, Toho University, 5-21-16 Omori-nishi, Otaku, Tokyo 143-8540, Japan. E-mail: yuuji.nishiwaki@med.toho-u.ac.jp

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.

Received July 12, 2012; Accepted November 14, 2012

Decision Editor: Stephen Kritchevsky, PhD

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

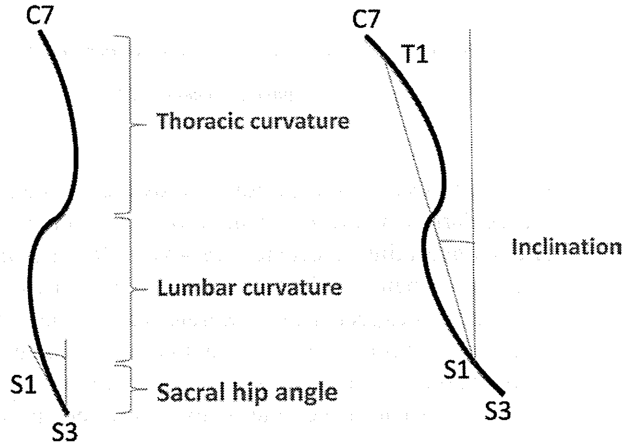


Figure 1. A schema illustrating the four parameters. Thoracic curvature: thoracic kyphosis (corresponds to Cobb angle between Th1 and Th12). Lumbar curvature: lumbar kyphosis (corresponds to Cobb angle between Th12 and S1). Sacral hip angle: the angle between a straight line from S1 to S3 and true vertical.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

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 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).

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.

Funding

This work was supported by a grant in aid from the Ministry of Health, Labour and Welfare, Japan (H20-Choujyu-009).

Acknowledgments

The authors would like to thank the staff of the City person & Health Division, Kurabuchi Branch Office, Takasaki City Hall, Gunma prefecture, Japan for their valuable help.

References

1. Ministry of Health, Labour and Welfare, Japan. 2011. http://www.mhlw.go.jp/toukei/saikin/hw/life/life11/dl/life11-14.pdf. Accessed July 26, 2012.
2. Nishiwaki Y, Kikuchi Y, Araya K, et al. Association of thoracic kyphosis with subjective poor health, functional activity and blood pressure in the community-dwelling elderly. *Environ Health Prev Med.* 2007;12:246–250.
3. Kado DM, Prenovost K, Crandall C. Narrative review: hyperkyphosis in older persons. *Ann Intern Med.* 2007;147:330–338.
4. Hirose D, Ishida K, Nagano Y, Takahashi T, Yamamoto H. Posture of the trunk in the sagittal plane is associated with gait in community-dwelling elderly population. *Clin Biomech (Bristol, Avon).* 2004;19:57–63.
5. Takahashi T, Ishida K, Hirose D, et al. Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int.* 2005;16:273–279.
6. Mannion AF, Knecht K, Balaban G, Dvorak J, Grob D. A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. *Eur Spine J.* 2004;13:122–136.
7. Post RB, Leferink VJ. Spinal mobility: sagittal range of motion measured with the SpinalMouse, a new non-invasive device. *Arch Orthop Trauma Surg.* 2004;124:187–192.
8. Michikawa T, Nishiwaki Y, Kikuchi Y, et al. Gender-specific associations of vision and hearing impairments with adverse health outcomes in older Japanese: a population-based cohort study. *BMC Geriatr.* 2009;9:50.
9. Michikawa T, Nishiwaki Y, Asakura K, et al. Sunlight exposure may be a risk factor of hearing impairment: a community-based study in Japanese older men and women. *J Gerontol A Biol Sci Med Sci.* 2012;68:96–103.
10. Nishiwaki Y, Michikawa T, Yamada M, Eto N, Takebayashi T; Kurabuchi Study Group. Knee pain and future self-reliance in older adults: evidence from a community-based 3-year cohort study in Japan. *J Epidemiol.* 2011;21:184–190.
11. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of adl: a standardized measure of biological and psychosocial function. *JAMA.* 1963;185:914–919.
12. Nishiwaki Y, Michikawa T, Eto N, Takebayashi T. Body mass index misclassification due to kyphotic posture in Japanese community-dwelling adults aged 65 years and older. *J Gerontol A Biol Sci Med Sci.* 2011;66:326–331.
13. Leech JA, Dulberg C, Kellie S, Pattee L, Gay J. Relationship of lung function to severity of osteoporosis in women. *Am Rev Respir Dis.* 1990;141:68–71.
14. Lombardi I Jr, Oliveira LM, Mayer AF, Jardim JR, Natour J. Evaluation of pulmonary function and quality of life in women with osteoporosis. *Osteoporos Int.* 2005;16:1247–1253.
15. Kado DM, Huang MH, Nguyen CB, Barrett-Connor E, Greendale GA. Hyperkyphotic posture and risk of injurious falls in older persons: the Rancho Bernardo Study. *J Gerontol A Biol Sci Med Sci.* 2007;62:652–657.
16. Ryan SD, Fried LP. The impact of kyphosis on daily functioning. *J Am Geriatr Soc.* 1997;45:1479–1486.
17. Sakamitsu T, Urabe Y, Yamamoto T. Relationship of kyphosis with balance and walking ability in the elderly. *Rigakuryoho Kagaku.* 2007;22:489–494 (in Japanese with English abstract).
18. Ishikawa Y, Miyakoshi N, Kasukawa Y, Hongo M, Shimada Y. Spinal curvature and postural balance in patients with osteoporosis. *Osteoporos Int.* 2009;20:2049–2053.
19. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporos Int.* 2005;16:1004–1010.
20. Thomas DP, Whitney RJ. Postural movements during normal standing in man. *J Anat.* 1959;93:524–539.
21. Asmussen E. The weight-carrying function of the human spine. *Acta Orthop Scand.* 1960;29:276–290.
22. Woodhull AM, Maltrud K, Mello BL. Alignment of the human body in standing. *Eur J Appl Physiol Occup Physiol.* 1985;54:109–115.
23. Arita C, Kobayashi I. The analysis of the posture of the senile. *Rinshouseikeigeka.* 1980;15:115–122 (in Japanese).
24. Harada T, Motegi M, Okazima Y, Hasegawa K, Abe H, Tsuruoka H. Posture of the aged. *Sougouriha.*1994;22:133–136 (in Japanese).
25. Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP. Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. *Spine.* 2009;34:E599–E606.
26. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, Schwab F. The impact of positive sagittal balance in adult spinal deformity. *Spine.* 2005;30:2024–2029.
27. Hatake K, Nakano T, Ochi T, Inaba D, Yasuoka H. Comparison of spinal alignment in healthy women and old women with vertebral compression fracture –Consideration of compensated spinal alignment. *Therap Res.* 2008;29:597–600 (in Japanese).
28. Miyazaki J, Murata S, Otao H, Horie J, Murata J, Suzuki S. Relationship between physical function and spinal sagittal plane alignment of elderly men. *Rigakuryoho Kagaku.* 2009;24:907–911 (in Japanese with English abstract).
29. Iwaya T, Shirakihara N, Tobimatu Y. The effects of low back pain on physical and social function in elderly people living in rural area. *J Jpn Soc Lumbar Spine Disord.* 2005;11:27–34 (in Japanese).
30. Kai Y, Murata S, Otao H, et al. A relationship between spinal deformity and lower limb muscle strength in community-dwelling elderly females. *Rigakuryoho Kagaku.* 2009;24:45–48 (in Japanese with English abstract).
31. Mori S. Guaging the impact of vertebral compression fractures and spinal deformity on the level of daily activity in patients with osteoporosis. *J Jpn Soc Lumbar Spine Disord.* 2002;8:58–63 (in Japanese with English abstract).

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

[*1)] Yuji NISHIWAKI，東邦大学医学部，社会医学講座衛生学分野
[*2)] Takehiro MICHIKAWA，独立行政法人国立環境研究所環境健康研究センター，環境疫学研究室

Activity of daily living and kyphotic posture

Key words：Kyphosis, Activity of daily living, Posture

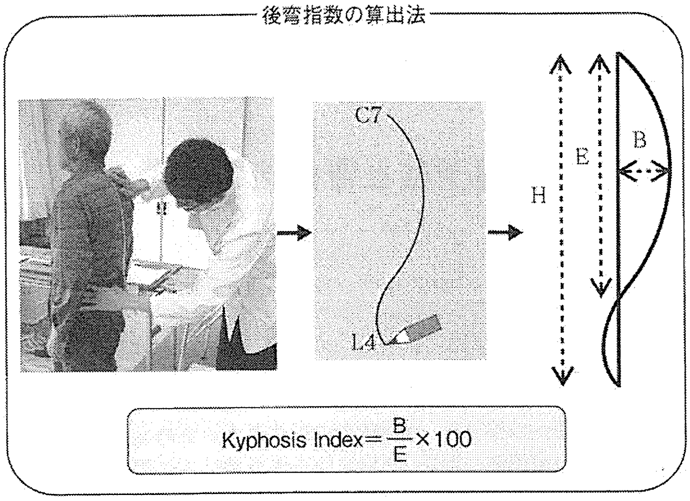


図 1　後弯指数（kyphosis index）の測定

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

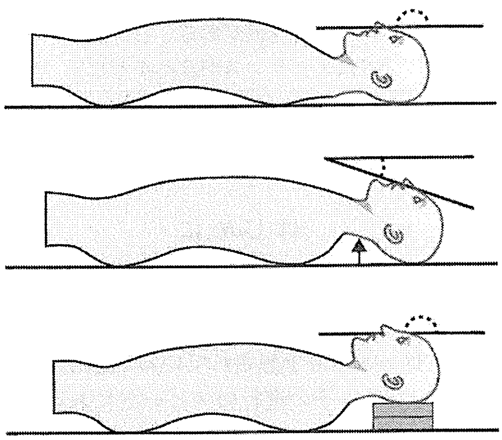


図 2　Occiput-to-table distance の測定

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

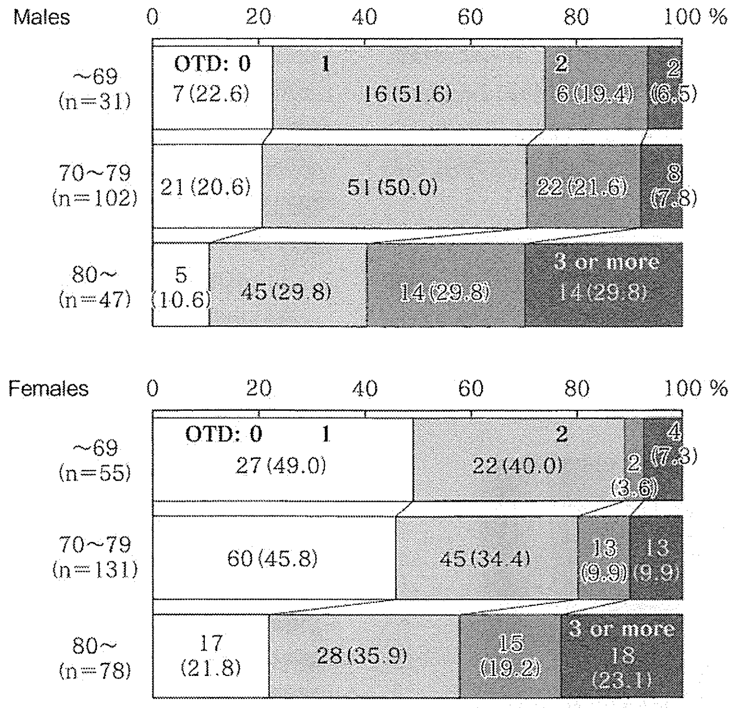


図 3　Occiput-to-table distance の性・年齢別分布（65 歳以上 444 名のデータ）

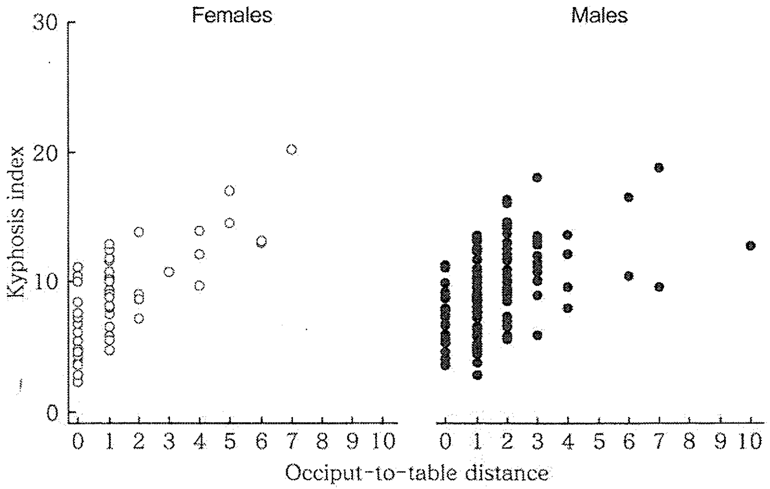


図 4　後弯指数と occiput-to-table distance の相関

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。

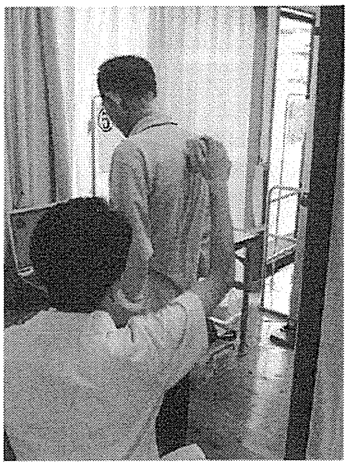
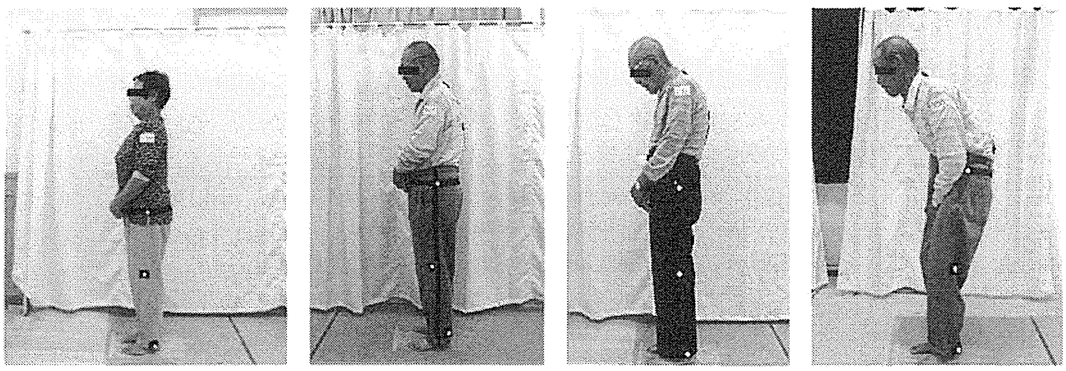


図 5 脊柱形状測定デバイスによる計測

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

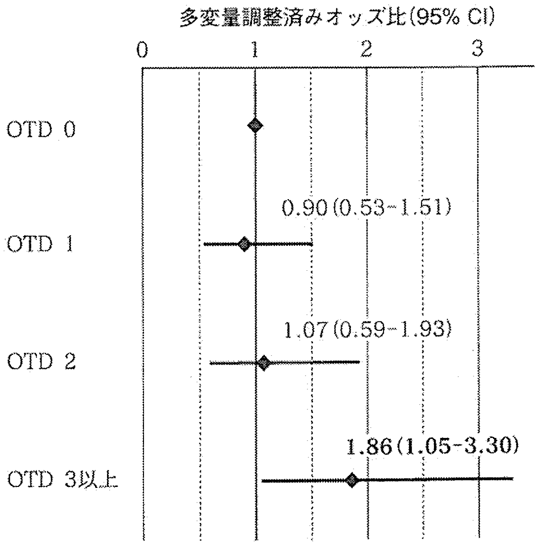


図 7 後弯と複合アウトカム（ADL 低下＋死亡）との関連

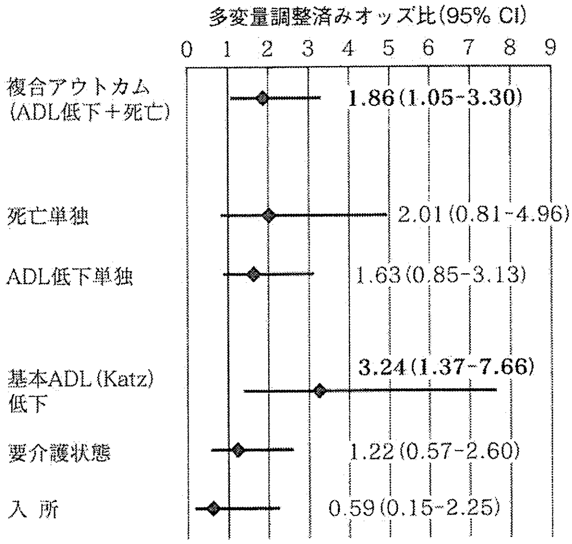


図 8 OTD 3 以上の後弯と個別アウトカム

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。

文　献

1) Milne JS et al：Age effects in kyphosis and lordosis in adults. Ann Hum Biol **1**：327—337, 1974
2) Nishiwaki Y et al：Association of thoracic kyphosis with subjective poor health, functional activity and blood pressure in the community-dwelling elderly. Environ Health Prev Med **12**：246—250, 2007
3) Kado DM et al：Hyperkyphotic posture predicts mortality in older community-dwelling men and women；a prospective study. J Am Geriatr Soc **52**：1662—1667, 2004
4) Ryan SD et al：The impact of kyphosis on daily functioning. J Am Geriatr Soc **45**：1479—1486, 1997
5) Takahashi T et al：Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. Osteoporos Int **16**：273—279, 2005
6) Hirose D et al：Posture of the trunk in the sagittal plane is associated with gait in community-dwelling elderly population. Clin Biomech（Bristol, Avon）**19**：57—63, 2004
7) Kado DM et al：Hyperkyphotic posture and risk of injurious falls in older persons；the Rancho Bernardo Study. J Gerontol A Biol Sci Med Sci **62**：652—657, 2007
8) Masunari N et al：Height loss starting in middle age predicts increased mortality in elderly. J Bone Miner Res［Epub 2011 Sep 19］

*　　　*　　　*

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。