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Original article

Increasing postural sway in rural-community-dwelling elderly persons with knee osteoarthritis

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Abstract
Background. The purpose of this study was to clarify the influence of pain and radiographic findings of osteoarthritis (OA) of the knee on postural stability in rural-community-dwelling elderly persons.
Methods. A total of 314 participants, consisting of 98 men and 216 women, aged 55 to 83 years, were investigated. Subjects were classified into four groups according to the symptoms and radiographic findings: Normal; Pain (pain without radiographic OA); Asymptomatic OA (radiographic OA without pain); Symptomatic OA (pain with radiographic OA). Knee pain was defined as unilateral or bilateral pain of the knee that had persisted for more than 1 month. Radiographic OA was defined as grades 2–4 according to the Kellgren and Lawrence criteria. The movement of the center of pressure (COP) was measured using a force platform to quantify postural sway.
Results. Among the men, subjects in the Asymptomatic and Symptomatic OA groups showed higher values of the envelopment area tracing by the movement of the COP (E AREA) and the distance of the movement of the COP per second (LNG/TIME) under closed-eyes condition. Among the women, subjects in the Asymptomatic and Symptomatic OA groups showed higher values of E AREA and LNG/TIME under both open- and closed-eyes conditions. In the regression models consisting of the variables pain and radiographic OA, all estimates for pain were less than zero in both sexes. The value was significant only on the E AREA under closed-eyes conditions in women. On the other hand, all estimates for radiographic OA were higher than zero for both sexes. These values were significant for E AREA and LNG/TIME under open-eyes conditions in women, and E AREA and LNG/TIME under closed-eyes conditions in both sexes.
Conclusions. Subjects with OA showed greater postural sway than those without it. Only radiographic OA was a significant factor for increasing postural sway.

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Introduction

Impaired balance control is one of the most important risk factors for falls.[1,2] Numerous studies have reported that elderly persons manifest deteriorating balance function, as evidenced by increased postural sway on the movement of the center of the pressure (COP)[3,4] or velocity.[5,6]

Postural stability is controlled by the motor, sensory, and cognitive systems.[7] Elderly persons showed significant increases in the absolute latency of distal muscle response and impairment of sensory integration abilities under conditions of reduced or conflicting sensory information.[8] They have also been found to have decreased muscle strength and mass.[9,10] Moreover, sensory systems showed age-related functional declines that affect balance control.[8,11]

Osteoarthritis (OA) of the knee is one of the major causes of reduced activities of daily living and lowers the quality of life in the elderly.[12,13] Estimated population prevalence in the elderly varies from 26% to 63%, depending on age and sex.[14,15] Subjects with knee OA show reduced muscle strength and proprioception of the knee joint.[16,17] The knee is the most commonly afflicted weight-bearing joint, and knee OA has also been implicated as a risk factor for falls by the elderly.[18] Therefore, an understanding of the ability to balance the body and prevent falling by elderly subjects with knee OA is a pressing issue.

Previous studies reported that subjects with knee OA displayed greater postural sway than those without it.[19–22] However, the studies have some limitations. First, control groups were not subjected to radiographic testing, and it was not proven that they did not have OA. Second, the assessment was done in men and women together.

In the present study, both platform measures of balance and radiographic examination were performed in all subjects. The purpose of this study was to clarify the influence of pain and radiographic findings of OA of the knee on postural stability in community-dwelling elderly persons of both sexes.

Materials and methods

Subjects

A comprehensive health examination program (CHEP) for inhabitants aged more than 39 years has been conducted in Y town, a rural area of southern Hokkaido, Japan, every August since 1982. The total population of Y town is about 17 500, with persons aged more than 55 years accounting for about 30%. Approximately 20 % of them engage in agriculture or fishery. All subjects were informed as to the aims of the study and provided consent to participate. The CHEP comprised internal medical examinations, orthopedic and physical functional examinations, and psychological tests. This study was approved by the local ethics committee of Y town. The total number of the participants in this CHEP was 882 (311 men, 571 women), and the exercise was conducted from August 3 to 5, 2001.

The inclusion criteria for this study were age 55–84 years, participation at examinations for orthopedic and physical function, ability to stand independently for more than 1 minute to obtain platform measures, and completion of all three examinations (radiographic examinations of knee, platform measures, and recording of present knee pain). Exclusion criteria were severe disability in walking and standing and the presence of equilibrium disturbance due to dysfunction of the central or peripheral nervous systems (which would result in platform measure patterns different from those of normal adults).[23]

Finally, a total of 311 subjects (95 men, 216 women) were included in this study. The mean age of the men was 67.7 years (range 59–83 years), and that of the women was 67.4 years (range 55–83 years). Subjects were classified into four groups according to their symptoms and radiographic findings: Normal, Pain, Asymptomatic OA, Symptomatic OA. The Normal group was defined as having neither pain nor radiographic findings of OA in either knee. The Pain group was defined as having knee pain without radiographic findings of OA in either unilateral or bilateral knees. The Asymptomatic OA group was defined as showing radiographic findings of OA without pain in either unilateral or bilateral knees. The Symptomatic OA group had knee pain as well as radiographic findings of OA in either unilateral or bilateral knees.

Table 1. Subjects' anthropometric data

Parameter	Men					Women				
	Normal (*n* = 66)	Pain (*n* = 15)	Asymptomatic OA (*n* = 8)	Symptomatic OA (*n* = 6)	*P*	Normal (*n* = 105)	Pain (*n* = 27)	Asymptomatic OA (*n* = 38)	Symptomatic OA (*n* = 46)	*P*
Age (years)	67.3 ± 0.7	69.1 ± 1.3	71.3 ± 2.6	71.8 ± 2.5	0.08	66.6 ± 0.5	67.2 ± 1.2	70.3 ± 0.9	69.7 ± 0.9	<0.001
Height (cm)	163.3 ± 0.1	161.2 ± 1.3	162.2 ± 2.3	161.5 ± 1.9	0.46	150.0 ± 0.5	150.4 ± 1.3	150.2 ± 1.1	148.2 ± 0.7	0.25
BMI	23.7 ± 0.4	23.3 ± 0.5	24.0 ± 1.1	24.2 ± 1.3	0.94	23.3 ± 0.3	23.3 ± 0.5	24.5 ± 0.4	25.9 ± 0.5	<0.001

Means ± standard error
BMI, body mass index; OA, osteoarthritis

Table 2. Mean postural stability indices according to the Kellgren-Lawrence criteria

	Men, by grade			Women, by grade		
Parameter	0 (*n* = 73)	1 (*n* = 8)	2–4 (*n* = 14)	0 (*n* = 110)	1 (*n* = 23)	2–4 (*n* = 83)
Open-eyes						
E AREA (cm^2)	2.76 ± 0.16	2.88 ± 0.66	2.98 ± 0.17	2.37 ± 0.10	2.38 ± 0.25	3.11 ± 0.17
LNG/TIME (cm/s)	1.80 ± 0.07	1.98 ± 0.36	2.25 ± 0.19	1.53 ± 0.04	1.46 ± 0.07	1.84 ± 0.05
DEV OF MX (cm)	−0.24 ± 0.09	0.13 ± 0.25	−0.18 ± 0.18	−0.14 ± 0.07	0.05 ± 0.10	−0.16 ± 0.08
DEV OF MY (cm)	−0.62 ± 0.18	−0.66 ± 0.56	−0.58 ± 0.44	−0.57 ± 0.12	−0.82 ± 0.27	−0.33 ± 0.16
Closed-eyes						
E AREA (cm^2)	4.19 ± 0.30	4.63 ± 0.76	6.90 ± 1.22	3.16 ± 0.14	3.49 ± 0.45	4.09 ± 0.23
LNG/TIME (cm/s)	2.75 ± 0.15	3.07 ± 0.42	4.05 ± 0.67	2.15 ± 0.06	2.09 ± 0.12	2.58 ± 0.10
DEV OF MX (cm)	−0.32 ± 0.09	0.15 ± 0.30	−0.28 ± 0.24	−0.18 ± 0.08	−0.15 ± 0.12	−0.16 ± 0.08
DEV OF MY (cm)	−0.06 ± 0.20	−0.13 ± 0.38	−0.25 ± 0.44	−0.01 ± 0.13	−0.37 ± 0.25	0.08 ± 0.15
Romberg quotient	1.65 ± 0.10	1.99 ± 0.38	2.22 ± 0.33	1.44 ± 0.06	1.59 ± 0.17	1.44 ± 0.08

Means ± standard error
See the text for an explanation of the abbreviations

Interview concerning knee pain

Participants were asked about the presence of knee pain during the physical test by the orthopedic surgeon. Knee pain was defined as unilateral or bilateral pain of the knee that had persisted for more than 1 month. The time at which pain appeared was not considered.

Radiographic assessment

Posteroanterior weight-bearing radiographs with the knee in 45° of flexion were obtained.[24] Subjects with radiographic OA were defined as those with radiographic findings of grades 2–4 according to the Kellgren and Lawrence criteria.[25] Radiographic assessment was done by one senior orthopedic surgeon (Y.H.), who was blind to patient information.

Platform measurements of balance

Static postural stability was assessed using a stable force platform; GS-30 (Anima, Tokyo, Japan). The machine is designed to assess the movement of the center of pressure (COP) from three verticality load sensors put on corners of an isosceles triangle as that of the center of gravity in a horizontal plane. The balance test procedure was described in detail in a previous article.[4] Briefly, the recording was carried out in the corner of a gymnastics hall. All participants were instructed to stand steadily on the foot plate without their shoes and with their arms at their sides and feet close together. The examination was performed twice, each lasting 30 s, under open- and closed-eyes conditions. The authors assessed the following five posturographic variables for assessment: envelopment area tracing by the movement of the COP (E AREA), distance of the movement of the COP per second (LNG/TIME), mean deviation of the COP along the X axis (DEV OF MX) and Y axis (DEV OF MY), and the ratio of E AREA under closed-eyes condition to E AREA under open–eyes condition (Romberg quotient).

Statistical analysis

First, the authors calculated the sex-specific mean indices of age, height, and body mass index (BMI) of the four groups. Second, the indices of postural stability were adjusted for these anthropometric potential confounders using multiple linear regression models. Finally, to access the individual effects of pain and radiographic OA findings on postural stability, the authors introduced the parameters of pain, radiographic OA findings, and their interaction in the regression models. All analyses were conducted using SAS release 8.2 (SAS Institute, Cary, NC, USA). $P < 0.05$ was considered to indicate statistical significance.

Results

Anthropometric data are shown in Table 1. They showed no significant differences between any of the four groups for the men, whereas age and BMI were significantly different for the women in the four groups. The mean postural stability indices according to the Kellgren and Lawrence criteria are presented in Table 2. Postural stability indices adjusted by age, height, and BMI are presented in Table 3. In the men, under closed-eyes condition the LNG/TIME was significantly different ($P = 0.03$) and the E AREA was marginally different ($P = 0.05$) in the four groups. Subjects in the Pain group showed the lowest values of E AREA and LNG/TIME under the closed-eyes condition. On the

Table 3. Mean postural stability indices adjusted by age, height, and BMI

Parameter	Men					Women				
	Normal (n = 66)	Pain (n = 15)	Asymptomatic OA (n = 8)	Symptomatic OA (n = 6)	P	Normal (n = 105)	Pain (n = 27)	Asymptomatic OA (n = 38)	Symptomatic OA (n = 46)	P
Open-eyes										
E AREA (cm^2)	2.98 ± 0.16	2.66 ± 0.44	2.66 ± 0.33	3.32 ± 0.52	0.67	2.44 ± 0.14	2.24 ± 0.25	3.25 ± 0.21	3.05 ± 0.20	<0.01
LNG/TIME (cm/s)	1.95 ± 0.08	1.78 ± 0.16	1.99 ± 0.21	2.44 ± 0.25	0.19	1.54 ± 0.05	1.57 ± 0.08	1.88 ± 0.07	1.80 ± 0.06	<0.001
DEV OF MX (cm)	−0.25 ± 0.10	−0.05 ± 0.20	0.12 ± 0.27	−0.57 ± 0.32	0.36	0.03 ± 0.08	−0.23 ± 0.14	−0.30 ± 0.12	−0.09 ± 0.11	0.10
DEV OF MY (cm)	−0.59 ± 0.20	−0.76 ± 0.42	−0.39 ± 0.56	−0.71 ± 0.65	0.96	−0.60 ± 0.15	−0.43 ± 0.27	−0.25 ± 0.22	−0.51 ± 0.21	0.63
Closed-eyes										
E AREA (cm^2)	4.70 ± 0.37	3.88 ± 0.77	6.27 ± 1.02	7.36 ± 1.20	0.05	3.55 ± 0.19	2.92 ± 0.34	4.52 ± 0.29	3.68 ± 0.27	<0.01
LNG/TIME (cm/s)	3.06 ± 0.19	2.51 ± 0.39	3.36 ± 0.51	4.66 ± 0.60	0.03	2.20 ± 0.08	2.06 ± 0.15	2.75 ± 0.13	2.44 ± 0.12	<0.01
DEV OF MX (cm)	−0.21 ± 0.11	−0.48 ± 0.22	−0.07 ± 0.29	−0.64 ± 0.35	0.40	−0.06 ± 0.08	−0.33 ± 0.15	−0.34 ± 0.12	−0.07 ± 0.12	0.13
DEV OF MY (cm)	0.02 ± 0.21	−0.40 ± 0.44	0.08 ± 0.58	−0.50 ± 0.68	0.74	−0.10 ± 0.15	0.18 ± 0.27	0.11 ± 0.22	−0.03 ± 0.21	0.86
Romberg quotient	1.75 ± 0.11	1.57 ± 0.24	2.27 ± 0.32	2.11 ± 0.38	0.28	1.56 ± 0.07	1.34 ± 0.13	1.48 ± 0.11	1.36 ± 0.11	0.29

Means ± standard error

other hand, subjects in the Asymptomatic and Symptomatic OA groups showed higher values for E AREA and LNG/TIME than did those in the Normal and Pain groups under closed-eyes condition. For women, the E AREA and LNG/TIME were significantly different in the four groups under both open- and closed-eyes conditions. Subjects in the Pain group had lowest E AREA values under both open- and closed-eyes conditions and LNG/TIME values under the closed-eyes condition. On the other hand, subjects in the Asymptomatic and Symptomatic OA groups had higher E AREA and LNG/TIME values than did those in the Normal and Pain groups under both open- and closed-eyes conditions. None of the Dev of MX and MY under both open- and closed-eyes conditions and Romberg quotient were significantly different between any of the four groups for either Sex.

In the regression models consisting of the variables pain, radiographic OA, and their interaction term with potential confounders, no interaction variables were significant. Therefore, models without interaction variables were thought to be defensible. Table 4 shows the results from these models without interaction. All estimates for pain were less than zero for both sexes, and the value was significant only on the E AREA under closed-eyes condition in women. On the other hand, all estimates for radiographic OA were higher than zero for both sexes. These values were significant for E AREA and LNG/TIME under closed-eyes condition in men and for E AREA and LNG/TIME under both open- and closed-eyes conditions in women. In the regression models, only radiographic OA was a significant factor for increasing postural sway.

Discussion

In this study, subjects with knee OA showed greater postural sway under closed-eyes condition among men and under both open- and closed-eyes conditions among women. Compared with reference values of postural stability in community-dwelling elders presented in a previous report,[4] the symptomatic OA group men showed approximately 1.8-fold values in E AREA and LNG/TIME under closed-eyes conditions. Higher E AREA and LNG/TIME values were also distinguished in women under open- and closed-eyes conditions in the symptomatic OA group. Our results supported those of previous studies that reported increased postural sway in persons with knee OA.[19–22] Wegener et al.[20] and Hinman et al.[22] found that subjects with knee OA displayed greater postural sway than age-matched controls under both open- and closed-eyes conditions. On the other hand, Hurley et al.[19] reported increasing postural sway only under the open-eyes

Table 4. Effects of pain and radiographic OA on the indices of postural stability

	Men			Women		
Parameter	Estimate	SE	*P*	Estimate	SE	*P*
Open-eyes						
E AREA (cm^2)						
Pain	–0.09	0.32	0.77	–0.16	0.19	0.41
Radiographic OA	0.04	0.38	0.92	0.80	0.20	<0.001
LNG/TIME (cm/s)						
Pain	–0.03	0.16	0.83	–0.01	0.06	0.84
Radiographic OA	0.28	0.18	0.13	0.30	0.07	<0.001
Closed-eyes						
E AREA (cm^2)						
Pain	–0.37	0.74	0.62	–0.71	0.27	<0.01
Radiographic OA	2.28	0.86	0.01	0.86	0.28	<0.01
LNG/TIME (cm/s)						
Pain	–0.12	0.38	0.75	–0.21	0.12	0.07
Radiographic OA	0.99	0.44	0.03	0.47	0.12	<0.001

condition, not under the closed-eyes condition. One explanation for this difference may be differences in the assessment manner of the balance measures. The method of determining postural stability used by Hurley et al.[19] measured the mean angle of displacement of the center of gravity from the vertical, which differed from the measure of the movement of the COP used by Wegener et al.[20] and Hinman et al.[22]

In previous reports, the control groups consisted of subjects without knee pain, joint disorder, or past history of joint injury — not subjects in whom the absence of osteoarthrtic changes was proven by radiographic examination. In the present study, all subjects underwent radiographic examinations and were divided into four groups according to the clinical and radiographic findings. In our study, the influence of knee pain and radiographic OA change could be assessed separately. In the regression models consisting of the variables pain and radiographic OA, all estimates for radiographic OA were higher than zero for both sexes. These values were significant for E AREA and LNG/TIME under closed-eyes condition in men and for E AREA and LNG/TIME under both open- and closed-eyes conditions in women. On the other hand, all estimates for pain were less than zero in both sexes, and the value was significant only on the E AREA under closed-eyes condition in women. This means that morphological bone changes contributed to the increasing postural sway in both sexes, whereas pain exerted a less significant influence. This was demonstrated for the first time in a study of a large number of community-dwelling people.

Knee pain did not cause increasing postural sway in either sex in this study. Jadelis et al.[26] reported that knee pain does not appear to be related to balance in subjects with good muscle strength even though poor balance was associated with a higher pain level in the presence of weak knees. On the other hand, Hassan et al.[21] reported that 77 subjects with symptomatic and radiographic knee OA showed increased postural sway compared to 63 controls with asymptomatic and clinically normal knees. They demonstrated that knee pain was a significant predictor of increasing postural sway. This difference might be due to the fact that the control group was not proven to have no radiographic osteoarthritic changes.

Multiple factors seemed to be related to both knee OA and postural stability. Subjects with knee OA showed reduced knee strength and proprioception.[16,17] Slowed reaction time and muscle weakness were associated with increased postural sway.[27] Increased valgus or varus (or both) instability of the knee may cause increased postural sway. Moreover, whether the OA is unilateral or bilateral also may influence the postural stability. Therefore, more detailed studies are required to resolve these issues.

Balance training has been shown to improve postural stability.[28,29] Province et al.[30] reported that exercise that concentrated mainly on balance training led to an approximately 25% reduction in the risk of falls. Therefore, especially woman subjects with knee OA may be able to reduce their risk of falls by training in balance control. Pointing out their impaired ability of balance control to subjects with OA is important to prevent falling and the associated injuries.

There are caveats to this study. The subjects consisted of healthy candidates drawn from a rural area in Japan. It did not represent all community-dwelling subjects, and less-active subjects may have been underrepresented. Considerable differences existed among the four groups. Especially among the men, the number of subjects with OA was small compared with that of normal subjects. However, this study would be useful in the sense that it is the first report on community-dwelling persons to focus on the relation between knee OA and postural stability.

Conclusions

The authors examined the relation between postural stability and knee OA in community-dwelling elderly persons. All subjects were diagnosed according to clinical investigations and radiographic findings. Among the subjects with knee OA, men showed greater postural sway under closed-eyes condition and women under both open- and closed-eyes conditions. In the regression models consisting of the variables pain and radiographic OA, only radiographic OA was a significant factor for increasing postural sway.

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References

1. Tinetti ME, Williams TF, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. Am J Med 1986;80:429–34.
2. Lord SR, Ward JA, Williams P, Anstey KJ. Physiological factors associated with falls in older community-dwelling women. J Am Geriatr Soc 1994;42:1110–7.
3. Ring C, Nayak USL, Isaacs B. The effect of visual deprivation and proprioceptive change on postural sway in healthy adults. J Am Geriatr Soc 1989;37:745–9.
4. Masui T, Hasegawa Y, Matsuyama Y, Sakano S, Kawasaki M, Suzuki S. Gender differences in platform measures of balance in rural community-dwelling elders. Arch Gerontol Geriatr 2005;41:201–9.
5. Pyykkö I, Jäntti P, Aalto H. Postural control in elderly subjects. Age Ageing 1990;19:215–21.
6. Baloh RW, Fife TD, Zwerling L, Socotch T, Jacobson K, Bell T, et al. Comparison of static and dynamic posturography in young and older normal people. J Am Geriatr Soc 1994;42:405–12.
7. Woollacott MH. Systems contributing to balance disorders in older adults. J Gerontol A Biol Sci Med Sci 2000;55:M424–8.
8. Woollacott MH, Shumway-Cook A, Nashner LM. Aging and posture control: changes in sensory organization and muscular coordination. Int J Aging Hum Dev 1986;23:97–114.
9. Bemben MG, Massey BH, Bemben DA, Misner JE, Boileau RA. Isometric muscle force production as a function of age in healthy 20- to 74-yr-old men. Med Sci Sports Exerc 1991;23:1302–10.
10. Frontera WR, Hughes VA, Lutz KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. J Appl Physiol 1991;71:644–50.
11. Wolfson L, Whipple R, Derby CA, Amerman P, Murphy T, Tobin JN, et al. A dynamic posturaography study of balance in healthy elderly. Neurology 1992;42:2069–75.
12. Davis MA, Ettinger WH, Neuhaus JM, Mallon KP. Knee osteoarthritis and physical functioning: evidence from the NHANES I epidemiologic followup study. J Rheumatol 1991;18:591–8.
13. Guccione AA, Felson DT, Anderson JJ, Anthony JM, Zhang Y, Wilson PWF, et al. The effect of specific medical conditions on the functional limitations of elders in the Framingham Study. Am J Public Health 1994;84:351–8.
14. Petersson IF. Occurrence of osteoarthritis of the peripheral joints in European populations. Ann Rheum Dis 1996;55:659–61.
15. Yoshida S, Aoyagi K, Felson DT, Aliabadi P, Shindo H, Takemoto T. Comparison of the prevalence of radiographic osteoarthritis of the knee and hand between Japan and the United States. J Rheumatol 2002;29:1454–8.
16. Hayes KW, Falconer J. Differential muscle strength decline in osteoarthritis of the knee: a developing hypothesis. Arthritis Care Res 1992;5:24–8.
17. Marks R, Quinney HA, Wessel J. Proprioceptive sensibility in women with normal and osteoarthritic knee joints. Clin Rheumatol 1993;12:170–5.
18. Pandya NK, Draganich LF, Mauer A, Piotrowski GA, Pottenger L. Osteoarthritis of the knees increases the propensity to trip on an obstacle. Clin Orthop 2005;431:150–6.
19. Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Ann Rheum Dis 1997;56:641–8.
20. Wegener L, Kisner C, Nichols D. Static and dynamic balance response in persons with bilateral knee osteoarthritis. J Orthop Sports Phys Ther 1997;25:13–8.
21. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis 2001;60:612–8.
22. Hinman RS, Bennell KL, Metcalf BR, Crossley KM. Balance impairments in individuals with symptomatic knee osteoarthritis: a comparison with matched controls using clinical tests. Rheumatology 2002;41:1388–94.
23. Tokita T, Maeda M, Miyata H. The role of the labyrinth in standing posture regulation. Acta Otolaryngol 1981;91:521–7.
24. Rosenberg TD, Paulos LE, Parker RD, Coward DB, Scott SM. The forty-five-degree posteroanterior flexion weight-bearing radiograph of the knee. J Bone Joint Surg Am 1988;70:1479–83.
25. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. Ann Rheum Dis 1957;16:494–502.
26. Jadelis K, Miller ME, Ettinger WH Jr, Messier SP. Strength, balance, and the modifying effects of obesity and knee pain: results from the Observational Arthritis Study in Seniors (OASIS). J Am Geriatr Soc 2001;49:884–91.
27. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. J Gerontol 1991;46:M69–76.
28. Wolf SL, Barnhart HX, Ellison GL, Coogler CE. The effect of Tai Chi Quan and computerized balance training on postural stability in older subjects. Phys Ther 1997;77:371–81.
29. Yates SM, Dunnagan TA. Evaluating the effectiveness of a home-based fall risk reduction program for rural community-dwelling older adults. J Gerontol A Biol Sci Med Sci 2001;56:M226–30.
30. Province MA, Hadley EC, Hornbrook MC, Lipsitz LA, Miller JP, Mulrow CD, et al. The effects of exercise on falls in elderly patients: a preplanned meta-analysis of the FICSIT trials. JAMA 1995;273:1341–7.