

Research article

Comparison of performance-based measures among native Japanese, Japanese-Americans in Hawaii and Caucasian women in the United States, ages 65 years and over: a cross-sectional study

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Abstract

Background: Japanese (both in Japan and Hawaii) have a lower incidence of falls and of hip fracture than North American and European Caucasians, but the reasons for these differences are not clear.

Subjects and Methods: A cross-sectional study. We compared neuromuscular risk factors for falls using performance-based measures (chair stand time, usual and rapid walking speed, and grip strength) among 163 Japanese women in Japan, 681 Japanese-American women in Hawaii and 9403 Caucasian women in the United States aged 65 years and over.

Results: After adjusting for age, the Caucasian women required about 40% more time to complete 5 chair stands than either group of Japanese. Walking speed was about 10% slower among Caucasians than native Japanese, whereas Japanese-American women in Hawaii walked about 11% faster than native Japanese. Grip strength was greatest in Japan, which may reflect the rural farming district that this sample was drawn from. Additional adjustment for height, weight or body mass index increased the adjusted means of chair stand time and grip strength among Japanese, but the differences remained significant.

Conclusions: Both native Japanese and Japanese-American women in Hawaii performed better than Caucasians on chair stand time and walking speed tests, and native Japanese had greater grip strength than Japanese in Hawaii and Caucasians. The biological implications of these differences in performance are uncertain, but may be useful in planning future comparisons between populations.

Background

Hip fractures result in increased health care utilization, suffering, and functional disability, and are one of the

most serious fractures among elderly people [1]. Japanese (both in Japan and Hawaii) have a lower incidence of hip and other nonspine fractures than Caucasians in

North America or northern Europe [2–4]. This lower fracture rate among Japanese is not explained by greater bone mass [5–9].

The lower fracture rates might have resulted from a lower prevalence of risk factors for fractures among Japanese. Hip fractures usually occur after a fall, but there are multiple risk factors for hip fracture, including bone mass and fall-related factors [10,11]. We reported earlier that the incidence and prevalence of falls among Japanese (both in Japan and Hawaii) is approximately half that of Caucasians in North America and Britain [12,13], but the reason for these differences are not clear.

Risk factors for falls, such as dementia, visual impairment, stroke, previous falls, medications and environmental hazards have been reported in previous studies [14–20]. Most of these risk factors indicate difficulty with neurologic and musculoskeletal functions that contribute to physical stability [16]. Previous studies showed that performance-based measures of physical function are strongly associated with risk of falling among the elderly, including studies of two of the populations reported here [16,18,21]. We recently reported that Japanese women performed better than Caucasian women on some neuromuscular tests, but Caucasians performed better on others, and that the differences in performance did not explain the observed differences in rates of falls [22]. Nevertheless, some of the observed differences in performance may be associated with lower risk of hip fracture independent of falling, if they influence protective responses in the event of a fall. The purpose of the current study was to compare performance-based measures (chair stand time, usual and rapid walking speed, and grip strength) among native Japanese, Japanese-Americans in Hawaii and Caucasian women in United States aged 65 years and over, to explore whether there are any obvious differences in physical performance, because there are few studies comparing neuromuscular function between races [22]. Hypotheses generated from the current study may be useful in planning future studies to explore whether differences in performance-based characteristics might be responsible for differences in fracture risk between populations.

Subjects and Methods

Study sample

The sample of native Japanese women were participants of the Mitsugi Bone and Joint Study (MBJS), conducted between 1994 and 1995 on community-dwelling people in a rural farming area (Mitsugi town, Hiroshima prefecture, Japan). People aged 40 and over were invited by the local government to participate in the general health examinations (annual examinations mandated by the Japanese Health and Medical Services Law for the Elderly).

The MBJS was incorporated into the examinations being conducted in Mitsugi Public General Hospital. A total of 384 women participated in the MBJS. Published details are available concerning the MBJS [23].

The sample of Japanese-Americans living in Hawaii were women who participated in the Hawaii Osteoporosis Study (HOS) Examination 8, conducted between 1992 and 1994. Most HOS participants live in the city of Honolulu or its suburbs. Details concerning recruitment and examination of the HOS subjects have been described elsewhere [24,25]. Briefly, male subjects of the HOS were recruited from the Honolulu Heart Program (HHP), which is a prospective cohort study of coronary heart disease and stroke among men of Japanese ancestry born between 1900–1911 and living on the island of Oahu, Hawaii in 1965. Using the World War II Selective Service Roster, 11,148 eligible men were identified, and a total of 8,006 men participated in the first HHP examination during 1965–1968. In 1980, a 30% random sample of the men attending the third HHP examination, and their wives, if also of Japanese ancestry, were invited to participate in the HOS. A total of 1,379 men and 1,105 wives participated in the first HOS examination during 1981–1982. Subsequent examinations have been conducted at intervals of one to three years. The 726 wives aged 55 years and over were the focus of the eighth HOS examination.

The sample of Caucasians were women who participated in the Study of Osteoporotic Fractures (SOF), conducted between 1986 and 1988. From 1986 to 1988, women who able to walk and who were at least 65 years of age in Portland, Oregon; Minneapolis, Minnesota; Baltimore, Maryland; and the Monongahela Valley, Pennsylvania, were invited to participate through mailings to women on lists such as voter-registration lists [26]. The SOF group consisted of 9516 Caucasian women who had neither undergone bilateral hip replacement nor had an earlier hip fracture.

Analyses were limited to the 163 native Japanese, 681 Japanese-American and 9403 Caucasian women aged 65 years and over for whom measurements were available, to provide a comparable age range for three populations. All subjects gave written informed consent.

Measures

Height and weight were measured with the subjects in light clothing and without shoes. Body mass index (BMI) was calculated as $\text{weight}(\text{kg})/\text{height}(\text{m})^2$.

Chair stand time was measured as the time to stand up from a standard chair five times; the subjects were asked, if possible, to not use their arms for assistance [27]. Re-

Table 1: Characteristics of native Japanese, Japanese-Americans and Caucasian women.

| Characteristics | Native Japanese | | Japanese-Americans | | Caucasians | |
|--------------------------------------|-----------------|-----|---------------------------|-----|-----------------------------|------|
| | Mean | SD | Mean | SD | Mean | SD |
| | N = 163 | | N = 681 | | N = 9403 | |
| Age [range] (years) | 70.6 [65–85] | 4.9 | 74.6 ^a [65–92] | 4.6 | 71.6 ^{a,b} [65–99] | 5.3 |
| Height (cm) | 147.9 | 5.2 | 150.2 ^a | 6.1 | 159.2 ^{a,b} | 6.0 |
| Weight (kg) | 49.5 | 6.7 | 52.9 ^a | 9.3 | 66.4 ^{a,b} | 12.5 |
| Body mass index (kg/m ²) | 22.6 | 2.7 | 23.5 | 4.4 | 26.2 ^{a,b} | 4.6 |

a; $p < 0.05$ compared to native Japanese. b; $p < 0.05$ compared to Japanese-Americans.

sults were calculated as the average of two trials. Walking speed was calculated from the time required for subjects to walk a 6 meter course at their usual pace (usual walking speed), and at a rapid but safe pace (rapid walking speed). Usual walking speed was calculated as the average of two trials. Rapid walking speed was recorded as one trial. Grip strength of the dominant hand was measured using an hydraulic dynamometer (Jamar Hydraulic Hand Dynamometer Model J00105, Lafayette Instrument Company, Inc., IN, USA). Grip strength was calculated as the average of two trials.

Statistical analysis

Statistical analyses were performed using SAS version 6.12 software (SAS Institute, Cary, NC, USA). Comparisons among native Japanese, Japanese-American and Caucasian women were performed using general linear modeling methods. Analysis of variance was used to compare the characteristics of the subjects and unadjusted means of performance-based measures. Analysis of covariance was used to compare the adjusted means of performance-based measures.

Results

Characteristics of native Japanese, Japanese-Americans in Hawaii and Caucasian women on the United States mainland are shown in Table 1. The mean age of Japanese-American women was the oldest, 4 years older than native Japanese and 3 years older than Caucasian women ($p < 0.05$). Caucasian women had significantly greater body size (height, weight) and BMI than both Japanese groups. Japanese-American women had greater height and weight than native Japanese, but differences in BMI were not significant.

In each population, physical performance decreased with age; grip strength and walking speed (both usual and rapid) decreased, and chair stand time increased (Table 2). The extent of change with age (age 80+ vs 65–69 years) differed somewhat among the three populations for the chair stand test. The Caucasian women exhibited a larger age-related increase in time required to complete the chair stand test (37%), compared to the two Japanese groups (19–21%). Age-related declines in usual and rapid walking speed and grip strength were fairly consistent for all three groups of women (16–26%). These differences should be interpreted with caution, as there were very few Japanese women in the oldest age groups.

The age-adjusted means of performance-based measures differed among populations (Table 3). Both native Japanese and Japanese-American women in Hawaii performed better than Caucasians on the chair stand and walking examinations. The Caucasian women required about 40% more time to complete 5 chair stands than either group of Japanese. The chair stand performance of native Japanese was similar to that of Japanese-American women. Usual walking speed was about 10% slower among Caucasians than native Japanese, whereas Japanese-Americans in Hawaii walked about 11% faster than the native Japanese. Rapid walking speed was about 13% slower among native Japanese, and 17% slower among Caucasians than Japanese-Americans. No significant difference of rapid walking speed between native Japanese and Caucasians was found.

Grip strength was greatest in Japan, followed by Caucasians, Japanese-Americans in Hawaii. Grip strength was about 10% stronger among native Japanese than Cauca-

Table 2: Chair stand time, usual walking speed, rapid walking speed and grip strength by age group among native Japanese, Japanese-American and Caucasian women.

| Age group | Native Japanese | | | Japanese-Americans | | | Caucasians | | |
|------------------------------------|-----------------|------|-----------|--------------------|------|-----------|------------|------|-----------|
| | No. | Mean | 95%CI | No. | Mean | 95%CI | No. | Mean | 95%CI |
| Chair stand time (sec) | | | | | | | | | |
| 65–69 | 82 | 8.0 | 7.2–8.8 | 110 | 8.2 | 7.4–9.1 | 4028 | 11.4 | 11.2–11.7 |
| 70–74 | 50 | 8.7 | 7.7–9.8 | 264 | 8.5 | 8.0–9.1 | 2933 | 12.4 | 12.1–12.7 |
| 75–79 | 19 | 9.5 | 7.7–11.2 | 210 | 9.0 | 8.4–9.6 | 1475 | 13.2 | 12.8–13.6 |
| >80 | 12 | 9.5 | 7.5–11.6 | 66 | 9.9 | 8.9–10.9 | 906 | 15.6 | 15.2–16.1 |
| %difference* | | 18.8 | | | 20.7 | | | 36.8 | |
| Usual walking speed (m/sec) | | | | | | | | | |
| 65–69 | 82 | 1.08 | 1.02–1.15 | 113 | 1.18 | 1.11–1.25 | 3535 | 0.97 | 0.95–0.98 |
| 70–74 | 50 | 0.99 | 0.90–1.07 | 273 | 1.12 | 1.08–1.16 | 2557 | 0.90 | 0.88–0.91 |
| 75–79 | 19 | 0.89 | 0.75–1.03 | 218 | 1.01 | 0.96–1.06 | 1258 | 0.83 | 0.81–0.85 |
| >80 | 12 | 0.86 | 0.70–1.02 | 76 | 0.87 | 0.80–0.95 | 690 | 0.74 | 0.71–0.76 |
| %difference* | | 20.4 | | | 26.3 | | | 23.7 | |
| Rapid walking speed (m/sec) | | | | | | | | | |
| 65–69 | 82 | 1.41 | 1.32–1.50 | 113 | 1.55 | 1.46–1.64 | 3535 | 1.36 | 1.35–1.38 |
| 70–74 | 50 | 1.27 | 1.16–1.39 | 273 | 1.50 | 1.44–1.56 | 2556 | 1.28 | 1.26–1.30 |
| 75–79 | 19 | 1.13 | 0.95–1.32 | 218 | 1.38 | 1.31–1.44 | 1258 | 1.20 | 1.17–1.22 |
| >80 | 11 | 1.19 | 0.96–1.42 | 74 | 1.19 | 1.09–1.30 | 690 | 1.07 | 1.03–1.10 |
| %difference* | | 15.6 | | | 23.2 | | | 21.3 | |
| Grip strength (kg) | | | | | | | | | |
| 65–69 | 82 | 25.4 | 23.7–27.1 | 112 | 21.6 | 20.4–22.8 | 4034 | 22.9 | 22.6–23.1 |
| 70–74 | 50 | 23.1 | 20.9–25.3 | 274 | 19.9 | 19.1–20.7 | 2955 | 21.6 | 21.3–21.9 |
| 75–79 | 19 | 23.6 | 20.0–27.2 | 219 | 18.5 | 17.6–19.4 | 1485 | 20.5 | 20.2–20.9 |
| >80 | 12 | 20.7 | 16.5–24.8 | 76 | 16.3 | 14.9–17.7 | 929 | 18.6 | 18.2–19.1 |
| %difference* | | 18.5 | | | 24.5 | | | 18.8 | |

* %difference with age (age 80+ vs 65–69)

sians, whereas it was about 7% weaker among Japanese-Americans than Caucasians. Additional adjustment for body size (height, weight and BMI) increased adjusted means of chair stand time and grip strength among either group of Japanese, whose body size was smaller compared with Caucasians, but had little or no effect on the statistical significance, and the general relationships described above remained relatively unchanged.

Discussion

Since there have been few comparative studies of neuromuscular function between races [22], we compared performance-based measures among native Japanese, Japanese-American in Hawaii and Caucasian women in United States aged 65 and over after careful standardization. Both native Japanese and Japanese-American women in Hawaii had better performance than Caucasians on the chair stand and walking speed tests. Decreased performance on the chair stand test is associated

Table 3: Comparison of adjusted means in chair stand time, usual walking speed, rapid walking speed and grip strength among native Japanese, Japanese-Americans and Caucasians.

| | Native Japanese | | | Japanese-Americans | | | Caucasians | | |
|------------------------------------|-----------------|------|------|--------------------|-------------------|------|------------|---------------------|-------|
| | No. | Mean | SE | No. | Mean | SE | No. | Mean | SE |
| Chair stand time (sec) | | | | | | | | | |
| Unadjusted | 163 | 8.5 | 0.35 | 650 | 8.8 | 0.18 | 9342 | 12.4 ^{a,b} | 0.05 |
| Age | 163 | 8.8 | 0.34 | 650 | 8.1 | 0.17 | 9342 | 12.5 ^{a,b} | 0.04 |
| Age, height, weight | 163 | 9.9 | 0.32 | 637 | 9.0 ^a | 0.17 | 7969 | 12.1 ^{a,b} | 0.05 |
| Age, BMI | 163 | 9.1 | 0.32 | 637 | 8.5 | 0.16 | 7969 | 12.2 ^{a,b} | 0.05 |
| Usual walking speed (m/sec) | | | | | | | | | |
| Unadjusted | 163 | 1.01 | 0.02 | 680 | 1.07 ^a | 0.01 | 8040 | 0.90 ^{a,b} | 0.002 |
| Age | 163 | 1.00 | 0.02 | 680 | 1.11 ^a | 0.01 | 8040 | 0.90 ^{a,b} | 0.002 |
| Age, height, weight | 163 | 1.01 | 0.02 | 666 | 1.12 ^a | 0.01 | 7992 | 0.90 ^{a,b} | 0.002 |
| Age, BMI | 163 | 0.97 | 0.02 | 666 | 1.09 ^a | 0.01 | 7992 | 0.90 ^{a,b} | 0.002 |
| Rapid walking speed (m/sec) | | | | | | | | | |
| Unadjusted | 162 | 1.32 | 0.02 | 678 | 1.43 ^a | 0.01 | 8039 | 1.28 ^b | 0.003 |
| Age | 162 | 1.30 | 0.02 | 678 | 1.49 ^a | 0.01 | 8039 | 1.28 ^b | 0.003 |
| Age, height, weight | 162 | 1.30 | 0.02 | 664 | 1.49 ^a | 0.01 | 7991 | 1.28 ^b | 0.003 |
| Age, BMI | 162 | 1.25 | 0.02 | 664 | 1.46 ^a | 0.01 | 7991 | 1.28 ^b | 0.003 |
| Grip strength (kg) | | | | | | | | | |
| Unadjusted | 163 | 24.1 | 0.36 | 681 | 19.3 ^a | 0.18 | 9403 | 21.7 ^{a,b} | 0.05 |
| Age | 163 | 23.8 | 0.34 | 681 | 20.1 ^a | 0.17 | 9403 | 21.6 ^{a,b} | 0.05 |
| Age, height, weight | 163 | 26.3 | 0.34 | 666 | 21.8 ^a | 0.18 | 8005 | 21.5 ^a | 0.05 |
| Age, BMI | 163 | 24.2 | 0.34 | 666 | 20.3 ^a | 0.17 | 8005 | 21.7 ^{a,b} | 0.05 |

a; p < 0.05 compared to native Japanese. b; p < 0.05 compared to Japanese-Americans.

with an increased risk of falls [18] and hip fracture [10]. Slower gait speed was also an independent fall-related predictor of hip fracture [11]. Thus, better neuromuscular function in old age may partly explain why the rates of falls and hip fractures among Japanese are lower than those among North American Caucasians. Although grip strength is also reported to be associated with risk of falls and hip fractures [11,17], the difference did not consistently favor Japanese over Caucasians.

Life-long squatting behaviors, a component of traditional Japanese lifestyle, may have had a long-term effect on preventing falls and hip fractures [28–30]. Since Japanese elderly spent most of their lives using tatami mats and futon bedding, and Eastern-style toilets (all of which are within inches of ground level and require squatting), they may have developed a better sense of balance and lower extremity strength by sitting, squatting, and rising to stand from floor level. An international cross-cultural study among residents of Japanese and American nursing homes demonstrated maintenance of quadriceps

strength and fewer falls among Japanese [29]. A recent case-control study of risk factors for hip fractures in Japanese elderly revealed a lower risk among those sleeping in futon bedding than in Western-style beds [30]. These daily activities of the traditional Japanese lifestyle may in part contribute to better performance among native Japanese, which could help in preventing falls and hip fractures.

Grip strength was greatest in Japan, which may reflect aspects of physical activity in the rural farming district that this sample was drawn from, but information on physical activity was not available to explore this hypothesis. Many older people in rural Japan grow rice and vegetables using both manual labor and machinery. In contrast, the Japanese-Americans and Caucasians were drawn from urban/suburban settings.

Performance on all tests (chair stand time, walking speed and grip strength) decreased with age within each of the three populations, which is consistent with previous studies [27,31,32]. Age-related poor performance may have two distinct roles in the occurrence of hip fractures: it may not only increase the risk of falling but also influence an individual's speed, coordination, and protective responses during a fall [11,33]. Tests of neuromuscular performance may be useful in primary care and clinical practice because they are simple, recreate situations in which falls are likely to occur, and provide a dynamic, integrated assessment of physical capacity [34].

Some performance-based measures may depend on body size [27,32,35]. In the current study, Caucasian women had the greatest body size (height, weight and BMI), followed by Japanese-Americans in Hawaii, and then native Japanese women. Additional adjustment for body size increased adjusted means of chair stand time and grip strength among Japanese, which indicates that greater body size is associated with poorer chair stand performance, but with stronger grip strength.

Both neuromuscular impairments and femoral neck bone mass are independent predictors of the risk of hip fracture in elderly women, and their combined assessment improves the prediction of hip fractures [10,11]. Thus, intervention programs to prevent hip fractures may be most effective if they target both fall-related factors and maintenance of bone mass. Effective programs for improving neuromuscular function, such as exercise and strength training may reduce the risk of falling [18,36] and improve the effectiveness of protective responses during a fall [33], which may reduce the risk of hip fracture. This may be especially relevant among elderly women whose bone density is already considerably below the fracture threshold [33,37].

Geometric characteristics of the femur as well as falls may be important for hip fracture risk [38,39]. Japanese have shorter hip axis lengths than Caucasians, which may be related to the smaller body size of Japanese, and may partly explain the lower hip fracture risk among Japanese compared to Caucasians in the US [38,39]. However, the incidence of hip fracture among Japanese was similar to that among Caucasians in Hawaii, suggesting that factors other than hip axis length are important [40]. Measurements of hip axis length in native Japanese were not available for analysis in the current study.

This study had several limitations. The participants were community-dwelling women over the age of 65, so these findings may not be generalizable to men, younger women, or nursing home residents. Backgrounds of participants were different; native Japanese were drawn from a rural area, but Japanese-American and Caucasian women were from urban/suburban settings. Thus, the differences of performance-based measures among populations may be in part influenced by current or past differences in physical activity (including occupation), or other factors. Finally, we did not have data from more detailed neurologic or musculoskeletal examinations, or other risk factors for falls and fractures, such as dementia, visual impairment, stroke, previous falls, medications and environmental hazards, calcium intake, physical activity, previous fractures and family history of fractures, any of which may be associated with hip fracture risk [14–20,41].

In summary, performance on chair stand and walking tests of both native Japanese and Japanese-American women in Hawaii were better than Caucasians. These differences indicate better neuromuscular function in older Japanese that may confer advantages in balance and lower extremity strength. However, whereas the native Japanese had the greatest grip strength, on average, the Japanese in Hawaii had lower grip strength than Caucasians. The biologic significance of these observations are uncertain, but may partly explain the lower incidence of falls and hip fractures among Japanese compared to Caucasians. Other factors, such as differences in health, disease, medication use, risk taking, or social supports, may also contribute to the observed differences in the rates of falls and hip fractures [22]. Further study is needed to control potential confounders to determine if neuromuscular risk factors for falls are independent risk factors for hip fracture.

Competing interests

None declared

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References

- Cummings SR, Kelsey JL, Nevitt MC, O'Dowd KJ: **Epidemiology of osteoporosis and osteoporotic fractures.** *Epidemiol Rev* 1985, **7**:178-208
- Hagino H, Yamamoto K, Teshima R, Kishimoto H, Kuranobu K, Nakamura T: **The incidence of fractures of the proximal femur and the distal radius in Tottori prefecture, Japan.** *Arch Orthop Trauma Surg* 1989, **109**:43-44
- Hagino H, Yamamoto K, Ohshiro H, Nakamura T, Kishimoto H, Nose T: **Changing incidence of hip, distal radius, and proximal humerus fractures in Tottori Prefecture, Japan.** *Bone* 1999, **24**:265-270
- Ross PD, Norimatsu H, Davis JW, Yano K, Wasnich RD, Fujiwara S, Hosoda Y, Melton LJ III: **A comparison of hip fracture incidence among native Japanese, Japanese Americans, and American Caucasians.** *Am J Epidemiol* 1991, **133**:801-809
- Yano K, Wasnich RD, Vogel JM, Heilbrun LK: **Bone mineral measurements among middle-aged and elderly Japanese residents in Hawaii.** *Am J Epidemiol* 1984, **119**:751-764
- Norimatsu H, Mori S, Uesato T, Yoshikawa T, Katsuyama N: **Bone mineral density of the spine and proximal femur in normal and osteoporotic subjects in Japan.** *Bone Miner* 1989, **5**:213-222
- Kin K, Lee JH, Kushida K, Sartoris DJ, Ohmura A, Clopton PL, Inoue T: **Bone density and body composition on the Pacific rim: a comparison between Japan-born and U.S.-born Japanese-American women.** *J Bone Miner Res* 1993, **8**:861-869
- Davis JW, Novotny R, Ross PD, Wasnich RD: **The peak bone mass of Hawaiian, Filipino, Japanese, and white women living in Hawaii.** *Calcif Tissue Int* 1994, **55**:249-252
- Ross PD, He Y, Yates AJ, Coupland C, Ravn P, McClung M, Thompson D, Wasnich RD: **Body size accounts for most differences in bone density between Asian and Caucasian women.** *Calcif Tissue Int* 1996, **59**:339-343
- Cummings SR, Nevitt MC, Browner WS, Stone K, Fox KM, Ensrud KE, Cauley J, Black D, Vogt TM: **Risk factors for hip fracture in white women.** *N Engl J Med* 1995, **332**:767-773
- Dargent-Molina P, Favier F, Grandjean H, Baudoin C, Schott AM, Hauserr E, Meunier PJ, Breart G: **Fall-related factors and risk of hip fracture: the EPIDOS prospective study.** *Lancet* 1996, **348**:145-149
- Davis JW, Ross PD, Nevitt MC, Wasnich RD: **Incidence rates of falls among Japanese men and women living in Hawaii.** *J Clin Epidemiol* 1997, **50**:589-594
- Aoyagi K, Ross PD, Davis JW, Wasnich RD, Hayashi T, Takemoto T: **Falls among community-dwelling elderly in Japan.** *J Bone Miner Res* 1998, **13**:1468-1474
- Campbell AJ, Reinken J, Allan BC, Martinez GS: **Falls in old age: a study of frequency and related clinical factors.** *Age Ageing* 1981, **10**:264-270
- Prudham D, Evans JG: **Factors associated with falls in the elderly: a community study.** *Age Ageing* 1981, **10**:141-146
- Tinetti ME, Speechley M, Ginter SF: **Risk factors for falls among elderly persons living in the community.** *N Engl J Med* 1988, **319**:1701-1707
- Blake AJ, Morgan K, Bendall MJ, Dallosso H, Ebrahim SB, Arie TH, Fentem PH, Bassey EJ: **Falls by elderly people at home: prevalence and associated factors.** *Age Ageing* 1988, **17**:365-372
- Nevitt MC, Cummings SR, Kidd S, Black D: **Risk factors for recurrent nonsyncopal falls. A prospective study.** *JAMA* 1989, **261**:2663-2668
- Yasumura S, Haga H, Nagai H, Suzuki T, Amano H, Shibata H: **Rate of falls and the correlates among elderly people living in an urban community in Japan.** *Age Ageing* 1994, **23**:323-327
- Graafmans WC, Ooms ME, Hofstee HM, Bezemer PD, Bouter LM, Lips P: **Falls in the elderly: a prospective study of risk factors and risk profiles.** *Am J Epidemiol* 1996, **143**:1129-1136
- Davis JW, Ross PD, Nevitt MC, Wasnich RD: **Risk factors for falls and for serious injuries on falling among older Japanese women in Hawaii.** *J Am Geriatr Soc* 1999, **47**:792-798
- Davis JW, Nevitt MC, Wasnich RD, Ross PD: **A cross-cultural comparison of neuromuscular performance, functional status, and falls between Japanese and white women.** *J Gerontol A Biol Sci Med Sci* 1999, **54**:M288-292
- Aoyagi K, Ross PD, Huang C, Wasnich RD, Hayashi T, Takemoto T: **Prevalence of joint pain is higher among women in rural Japan than urban Japanese-American women in Hawaii.** *Ann Rheum Dis* 1999, **58**:315-319
- Heilbrun LK, Ross PD, Wasnich RD, Yano K, Vogel JM: **Characteristics of respondents and nonrespondents in a prospective study of osteoporosis.** *J Clin Epidemiol* 1991, **44**:233-239
- Worth RM, Kagan A: **Ascertainment of men of Japanese ancestry in Hawaii through World War II Selective Service registration.** *J Chronic Dis* 1970, **23**:389-397
- Cummings SR, Black DM, Nevitt MC, Browner WS, Cauley JA, Genant HK, SR Mascioli, Scott JC, Seeley DG, Steiger P: **Appendicular bone density and age predict hip fracture in women.** *JAMA* 1990, **263**:665-668
- Csuka M, McCarty DJ: **Simple method for measurement of lower extremity muscle strength.** *Am J Med* 1985, **78**:77-81
- Yamamoto K, Nakamura T, Kishimoto H, Hagino H, Nose T: **Risk factors for hip fracture in elderly Japanese women in Tottori Prefecture, Japan.** *Osteoporos Int* 1993, **3** Suppl 1:48-50
- Lipsitz LA, Nakajima I, Gagnon M, Hirayama T, Connelly CM, Izumo H, Hirayama T: **Muscle strength and fall rates among residents of Japanese and American nursing homes: an International Cross-Cultural Study.** *J Am Geriatr Soc* 1994, **42**:953-959
- Suzuki T, Yoshida H, Hashimoto T, Yoshimura N, Fujiwara S, Fukunaga M, T Nakamura, Yoh K, Inoue T, Hosoi T, et al: **Case-control study of risk factors for hip fractures in the Japanese elderly by a Mediterranean Osteoporosis Study (MEDOS) questionnaire.** *Bone* 1997, **21**:461-467
- Bassey EJ, Bendall MJ, Pearson M: **Muscle strength in the triceps surae and objectively measured customary walking activity in men and women over 65 years of age.** *Clin Sci* 1988, **74**:85-89
- Cauley JA, Petrini AM, LaPorte RE, Sandler RB, Bayles CM, Robertson RJ, Slemenda CW: **The decline of grip strength in the menopause: relationship to physical activity, estrogen use and anthropometric factors.** *J Chronic Dis* 1987, **40**:115-120
- Nevitt MC, Cummings SR, Hudes ES: **Risk factors for injurious falls: a prospective study.** *J Gerontol* 1991, **46**:M164-170
- Tinetti ME: **Performance-oriented assessment of mobility problems in elderly patients.** *J Am Geriatr Soc* 1986, **34**:119-126
- Bendall MJ, Bassey EJ, Pearson MB: **Factors affecting walking speed of elderly people.** *Age Ageing* 1989, **18**:327-332
- Tinetti ME, Doucette JT, Claus EB: **The contribution of predisposing and situational risk factors to serious fall injuries.** *J Am Geriatr Soc* 1995, **43**:1207-1213
- Grisso JA, Kelsey JL, Strom BL, Chiu GY, Maislin G, O'Brien LA, S Hoffman, Kaplan F: **Risk factors for falls as a cause of hip fracture in women.** *N Engl J Med* 1991, **324**:1326-1331
- Cummings SR, Cauley JA, Palermo L, Ross PD, Wasnich RD, Black D, Faulkner KG: **Racial differences in hip axis lengths might explain racial differences in rates of hip fracture. Study of Osteoporotic Fractures Research Group.** *Osteoporos Int* 1994, **4**:226-229
- Nakamura T, Turner CH, Yoshikawa T, Slemenda CW, Peacock M, Burr DB, Mizuno Y, Orimo H, Ouchi Y, Johnston CC Jr: **Do variations in hip geometry explain differences in hip fracture risk between Japanese and white Americans?** *J Bone Miner Res* 1994, **9**:1071-1076
- Ross PD, Huang C: **Hip fracture incidence among Caucasians in Hawaii is similar to Japanese. A population-based study.** *Aging Clin Exp Res* 2000, **12**:356-359
- PD Ross: **Osteoporosis. Frequency, consequences, and risk factors.** *Arch Intern Med* 1996, **156**:1399-1411