Calcif Tissue Int (1999) 64:263–266

Calcified Tissue International

Influence of Grip Strength on Metacarpal Bone Mineral Density in Postmenopausal Japanese Women: A Cross-Sectional Study

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Received: 24 February 1998 / Accepted: 7 August 1998

Abstract. Most published studies on the role of muscle strength in the maintenance of bone mineral density (BMD) focused on the relationship between specific muscle groups and adjacent bones, mostly in young and premenopausal women. This study examined the influence of grip strength on BMD of the metacarpal index in postmenopausal Japanese women. Subjects included 1168 postmenopausal women aged 40–70 years. BMD measurement was done with computed X-ray densitometry (CXD) by analyzing X-ray films of the right second metacarpal index. Grip strength was measured in both the dominant and nondominant hands using a squeeze dynamometer. Grip strength ($r = 0.2474$; $P = 0.0001$) and age ($r = -0.5443$; $P = 0.0001$) significantly correlated positively and negatively, respectively, with BMD. Physical activity ($r = 0.1318$; $P = 0.0001$) also correlated positively with BMD. Breastfeeding ($r = -0.1658$; $P = 0.0001$), however, correlated negatively with BMD. Subjects with a history of regular physical activity had higher grip strengths and BMD, than those with no physical activity. Adjustment for age, physical activity, calcium intake, BMI, breastfeeding, testing site, and menopausal type indicated a significant (P for trend $= 0.0013$) positive association of grip strength with BMD. Subjects with stronger grip strengths had a decreased risk for low BMD.

Key words: Grip strength — bone mineral density — Postmenopausal — Japanese women — Lifestyle.

In the past 20 years, various methods of bone densitometry have been introduced to evaluate the risk of osteoporosis in adults [1–4]. Most of these methods, especially linear radiation absorption techniques such as single photon absorptiometry (SPA) and dual photon absorptiometry (DPA) have low radiation exposure and good reproducibility [5]; however, these methods are of only moderate value in predicting the future risk of low bone mineral density (BMD) and subsequent fractures [5]. This is probably due to the fact that measurements of BMD look at only the end results of bone loss without taking into account the material characteristics of the skeletal segments, such as mechanical stimulation, elasticity, and protection against twisting and bending [5, 6]. Studies of the effects of muscle strength on BMD have produced interestingly different conclusions, but few have targeted postmenopausal Japanese women specifically [2, 4]. In this cross-sectional study, we investigated the relationship between muscle strength and the risk of low BMD in this clinically important population.

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Subjects and Methods

The study was performed from September 1996 to March 1997 in Ibaraki prefecture, Japan through the Prefectural Osteoporosis Screening Program. The program is a population-based study undertaken to investigate potential risk factors for osteoporosis in Ibaraki prefecture, Japan. Subjects included 1688 women gathered through 14 prefectural community health centers.

Exclusion Criteria

Exclusion criteria for the final study population were renal disease, insulin-dependent diabetes, liver disease, rheumatoid arthritis, malignancy, or chronic diseases that might affect the skeleton; abnormalities of the parathyroid, thyroid, and the adrenal glands; surgical conditions such as partial or total gastrectomy, and hysterectomy with or without oophorectomy; long-term immobilization, history of ammenorrhea and alcoholism; and prior use of estrogen replacement therapy (ERT), corticosteroids, diuretics, cytotoxic drugs, anabolic steroids, bisphosphonates, calcitonin, and vitamin D. Subjects who reported no menstruation for at least a year before the study without any medical reason were classified as natural menopausal. Of the 1688 participants, 520 women who were still premenopausal were excluded and those who had undergone surgical menopause ($n = 133$) were adjusted for in the final analysis. A self-administered questionnaire and interviews were used to collect data on lifestyle, physical activity reproductive history, and previous health conditions [22]. A physical activity question included type, frequency, and duration of activities, and specifically, questions on footsports (walking, running, jogging, and brisk walking); ball games (volleyball, lawn tennis, table tennis, gateball or croquet, badminton, softball, basketball, and golf); stretching (radio/TV stretching, weight and muscle training, and yoga); dancing (aerobic dance, traditional Japanese dance, jazz dance, and western folk dance); martial arts (kyuudo, kendo, karate, and taichi-chuan); and other sports (boating, canoeing, cycling, skiing, and mountaineering [22, 9]. Whenever questionnaire responses were incomplete, subjects were interviewed by trained research assistants or public health nurses for further information.

Bone Densitometry

Computed X-ray densitometry (CXD) and a bonalyzer (Teijin Ltd,

Table 1. Age-specific frequencies of subjects according to levels of metacarpal index BMD

Bone density level	BMD (mmAI)	40–49	50–59	60–69	70 & over	Total
Low	<2.3	6	122	232	74	434
High	⩾2.3	52	440	222	20	734
Total		58	562	454	94	1168

Tokyo, Japan) were used to analyze X-ray films of the right second metacarpal index finger. Two densitometers were used at all the screening facilities. Reliable calibration and stability of both densitometers were ensured by daily phantom measurements. The coefficient of variation (CV) for repeated measures (same technician examined the same X-ray film phantom 6 times) and daily (same technician examined the same X-ray film phantom for 9 days) was 0.70% and 1.45%, respectively. The inter-assessors (two technicians) reliability was 1.04% (CV). To examine the *in vivo* reliability, 15 normal subjects were analyzed: The *in vivo* precision was 1.31% (CV). Based on standards proposed by the health and welfare ministry of Japan, subjects with BMD < 2.3 mmAl were considered to have low BMD [6, 7]. All measurements were done by two trained technicians and assisted by three public health nurses. Detailed description of the densitometry methods can be found elsewhere [8–10].

Table 2. Correlations[a] between covariates and metacarpal index BMD in natural menopausal women

	n	r	*P*-value
Age (years)	1034	−0.5443	0.0001
Grip strength (kg)	1034	0.2474	0.0001
Physical activity (yes/no)	1033	0.1318	0.0001
Breastfeeding (yes/no)	940	−0.1658	0.0001
Body mass index (kg/m^2)	1034	−0.0476	NS
Calcium intake[b]	1034	−0.0179	NS

NS: not significant
[a] Spearman rank correlation coefficient
[b] Retrospective estimation of intake based on frequency of calcium-rich foods (Cauley et al [17]).

Muscle Strength Measurements

Muscle strength was measured as grip strength of both the dominant and the nondominant hands using the DM-100N squeeze dynamometer (Yagami Ltd., Tokyo, Japan). Three grip strength measurements were made for each hand and the mean of the three measurements was recorded. For the final analysis, only grip strength of the right hand was used. The CV for repeated grip strength measurements is within the 2.0–4.5% range for both children and adults. All analyses were done with the statistical analysis software (SAS) [21].

Results

Table 1 shows age-specific frequencies of subjects according to levels of BMD. Four hundred thirty-four women had BMD < 2.3 and 734 had BMD ⩾2.3. A greater proportion of the women were in their 50s and 60s. We found no significant variations in most of the covariates with respect to the category of BMD level. However, Spearman rank correlation coefficient (Table 2) indicated a significant negative and positive correlation of metacarpal index BMD with age (r = 0.5443; *P* = 0.0001) and grip strength (r = 0.2474; *P* = 0.0001), respectively. Previous physical activity (r = 0.1318; *P* = 0.0001) and breastfeeding (r = −0.1658; *P* = 0.0001) also correlated significantly with BMD. Table 3 shows age-specific means of BMD and grip strength (kg) according to history of physical activity. Mean BMD and grip strength for all women was 2.49 ± 0.33 mmA1 and 25.09 ± 5.14 kg, respectively. Subjects with a history of regular physical activity tended to have higher BMDs and grip strengths compared with those in the no physical activity category. Both grip strength and BMD tended to decrease with increasing age in both categories of physical activity. There were significant variations in BMD and grip strength with respect to the various types of physical activity (χ^2 = 54.23; *P* = 0.001). Subjects with a history of fall-related fractures had slightly lower BMD and grip strength (BMD = 2.26 ± 0.29; grip strength = 22.48 ± 3.93 kg) than those who had reported no fall-related fractures (BMD = 2.38 ± 0.28; grip strength = 23.97 ± 4.72 kg). Table 4 shows adjusted odds ratios for the risk of low BMD according to categories of grip strength. The risk for low BMD decreased with increasing grip strength. Subjects with higher grip strengths had the lowest risk for low BMD. Even after adjustment for potential confounding factors such as age (*P* for trend = 0.0002) physical activity, calcium intake, BMI, breastfeeding, testing site, and menopausal type (*P* for trend = 0.0013), increasing grip strength was still associated with a decreased risk for low BMD.

Discussion and Conclusions

We found a significant decrease in the risk for low BMD among subjects with increased grip strengths. Not surprisingly, most of the subjects with decreased risks for low BMD also displayed a history of regular physical activity, indicative of a role for muscle stimulation through physical activity in the maintenance of BMD [13–16]. Measurement of grip strength is less costly, less invasive, and in combination with metacarpal BMD measurements could provide a feasible way of predicting BMD with little discomfort to the subjects. The positive association of grip strength with metacarpal index BMD makes physiological sense because it takes into account the synergistic roles of muscle and bone in building the adult peak bone mass [5–8, 13–16]. Although the metacarpal index is composed mainly of cortical bone which tends to have a lower bone turnover, significant associations were observed with grip strength and physical activity in this and several other pieces of published literature, which also found grip strength to be an independent predictor of BMD [13–17]. Compared with those who had no history of fall-related fractures, we also observed that subjects who had reported history of fall-related fractures had slightly decreased grip strength and BMD, a trend that was equally evident in all the age groups (data not shown). The observations in this study offer a reminder that improved muscle strength through regular

Table 3. Age-specific BMD[a] and grip strengths (kg) of the 1168 subjects according to history of physical activity

	40–49 (n = 58)	50–59 (n = 562)	60–69 (n = 454)	70+ (n = 94)
No physical activity				
Grip strength	27.39 ± 4.48	24.55 ± 4.90	23.24 ± 5.29	19.89 ± 3.37
BMD	2.75 ± 0.25	2.51 ± 0.29	2.26 ± 0.22	2.08 ± 0.26
Regular physical activity				
Grip strength	28.19 ± 4.76	25.65 ± 4.71	23.51 ± 4.27	22.16 ± 4.18
BMD	2.77 ± 0.21	2.57 ± 0.26	2.28 ± 0.25	2.16 ± 0.28
All women				
Grip strength	27.92 ± 4.72	25.22 ± 4.80	23.33 ± 4.73	20.66 ± 4.33
BMD	2.77 ± 0.23	2.54 ± 0.28	2.27 ± 0.24	2.09 ± 0.26

[a] Values in mmAl

Table 4. Multiply adjusted odds ratios and 95% confidence intervals for low BMD according to grip strength

Grip strength	n	Odds ratios (95% CI)[a]	Odds ratios (95% CI)[b]
<20 kg	172	1	1
20–25 kg	456	0.96 (0.65–1.41)	0.99 (0.67–1.47)
25–29 kg	397	0.75 (0.50–1.13)	0.79 (0.53–1.21)
⩾30	143	0.33 (0.18–0.58)	0.36 (0.19–0.66)
P-value for trend		0.0002	0.0013

[a] Adjusted for age only
[b] Adjusted for age, physical activity, BMI, breastfeeding, calcium intake, testing site, and menopausal type (i.e., natural or surgical)

physical activity may be a good protection against the future risk of low BMD in this population. Stronger muscles through physical activity might also improve balance, physical strength, and flexibility thereby making falls and subsequent fractures less likely [14–16]. The cross-sectional nature of this study may require caution in interpreting the results. However, the association of muscle strength (grip strength) with a reduced risk for low metacarpal index BMD, may be of considerable importance in assessing the risk for low BMD in postmenopausal women, and merits further study.

Acknowledgments. Many thanks to the Ibaraki Prefectural government for allowing us access to the 14 community health centers, to Mr. Kouichi Kasagi of the University of Tsukuba Medical Computing Center for his help with data transfer, and to the University of Tsukuba Department of Epidemiology and Biostatistics for their help with this project.

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