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Original Article

Comparison of bone density on the dominant and nondominant sides between healthy elderly individuals and stroke patients

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Abstract. [Purpose] This study evaluated differences between healthy elderly individuals and stroke patients by comparing their dominant and nondominant sides. [Subjects and Methods] Thirty-five elderly individuals participated in this study and divided into a stroke group and a control group. The outcome measures were general characteristics and bone mineral density. Bone mineral density was evaluated by using the osteoporosis index. OsteoPro, T score, and Z score were used for the calcaneus region of the dominant side, and OsteoPro was used for that of the nondominant side. Data were analyzed by using the SPSS 12.0 software, paired-samples t-test, and independent-samples t-test. [Results] The T and Z scores showed no significant differences between the dominant and recessive sides in the control group. However, the stroke group showed significant differences in osteoporosis index, T score, and Z score between the paretic and nonparetic sides. Changes in the scores between the recessive and dominant sides showed significant differences between the two groups. [Conclusion] A positive relationship was found between physical activity and bone mineral density in the stroke patients. Therefore, improved physical activity can be beneficial by reducing osteoporosis in stroke patients.
Key words: Bone mineral density, Osteoporosis, Stroke

INTRODUCTION

Stroke impairs brain function via the obstruction of blood flow resulting from a blood clot or ruptured blood vessels, and causes permanent disability in patients[1]. Hemiplegia is commonly associated with a decrease in balance ability and postural control[2]. Impaired balance and increased postural sway are known to be associated with abnormal weight bearing on the lower extremities[3]. Gait disability is a common symptom that is observed in 80% of patients with stroke[4]. The study was performed according to the principles of the Declaration of Helsinki, and ethical approval was granted by the local committee of the institutional review board of the university hospital. The management of gait ability is an important goal in the process of therapy for stroke rehabilitation because gait is a significant element in the achievement of functional independence[5, 6].

Restricted movement of patients with paretic stroke leads to a reduction in muscular strength, load-bearing capacity on the nonparetic side, and physical activity. This in turn causes osteoporosis due to bone loss[7]. Many studies have been conducted

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to investigate the causes and characteristics of osteoporosis after stroke. Sato et al.[8] reported that increased bone resorption as a result of decreased motion induces bone loss. The incidence of osteoporosis and risk of fracture increase over time after a stroke[9, 10]. Related factors include the duration and extent of paralysis, patient age, serum calcium and 25-hydroxy vitamin D concentrations[11], diabetes mellitus, menopause, hyperthyroidism, and Cushing syndrome[12]. Osteoporosis is common in stroke patients and increases the risk of fractures. Osteoporotic fractures are difficult to treat and prone to complications; increase patient mortality[10, 13]; cause numerous socioeconomic problems, including increased hospitalization duration and medical expenses; and lead to increased difficulties for patients and their guardians. As changes in bone density of stroke patients affect rehabilitation outcomes, they are a significant factor to be considered in the treatment process[14].

Numerous studies have evaluated the influence of increased physical activity on stroke patients. However, only few studies have compared bone density between a healthy population and stroke patients. This study aimed to compare bone density between the dominant and nondominant sides of healthy elderly subjects aged >60 years and between the paretic and nonparetic sides of hemiplegic stroke patients.

SUBJECTS AND METHODS

This study enrolled 15 stroke patients aged $\geq$60 years who had lived in a sanatorium in D City for at least 6 months and 20 elderly individuals with no disease history as the control group. The stroke group consisted of 9 male and 6 female subjects, and the control group consisted of 4 male and 16 female subjects. The inclusion criteria were as follows: 1) could follow instructions and answer questions; 2) capable of communication; 3) not taking any drug or substance that could affect bone density, such as alcohol or smoking; and 4) provided consent to participate in the study. The subjects' mean age was 73.2 years; mean height, 157 cm; mean weight, 56.2 kg; and mean body mass index, 22.5 kg/m^2 (Table 1).

To measure bone density, a quantitative ultrasonography device called OsteoPro (BM Tech, Korea) was used. After entering data on age, height, weight, and foot size in the device and performing zero-point calibration, bone density was measured at the right and left calcaneus. The subject sat with a straight back, and the central axis of the footplate was positioned between the second and third toes. During measurement, the subject was instructed to sit still. Osteoporosis index (OI), T score, and Z score were used to evaluate bone density.

OI is an index that optimally combines all factors that affect bone density. Z score was calculated by determining the difference between a certain subject's bone density and the mean bone density of an age- and gender-matched population, and then dividing this by the standard deviation of that population. T score was calculated by determining the difference between the bone density of a certain subject and the maximum bone density in the general 20-year-old population, and then dividing this by the standard deviation of that population. The World Health Organization has used T scores to define clinical cutoff values for osteoporosis in female adults. A T score of ≥-1.0 is defined as normal; a T score between -1.0 and -2.5, as osteopenia; and a T score of ≤-2.5, as osteoporosis[15, 16]. This study defined the change in bone density as the difference in bone density between the paretic and nonparetic sides in the stroke group, and between the dominant and nondominant sides in the control group.

After dividing the subjects into a stroke group and a control group, paired-samples t-tests were performed to analyze the OIs, T scores, and Z scores of the paretic and nonparetic sides in the stroke group, and those of the dominant and nondominant sides in the elderly group. Change in bone density was compared between the two groups by using an independent-samples t-test. All results are shown as mean $\pm$ standard deviation, and a p value of $\leq$0.05 was defined as statistically significant. All statistical processing of data was performed by using SPSS 12.0.

RESULTS

No significant difference in bone density was found between the dominant and nondominant sides in the control group in terms of OI, T score, or Z score (p>0.05; Table 2). In the stroke group, the OI, T score, and Z score for the nonparetic side were significantly higher than those for the paretic side (p<0.05; Table 2). Change in bone density was compared between the two groups based on the OIs, T scores, and Z scores. A significant difference was found between the two groups in terms of changes in OI, T score, and Z score (p<0.05; Table 3). Between the two groups, the highest OI, T score, and Z score values were obtained from the nonparetic side in the stroke group (Table 2).

DISCUSSION

In their study that focused on the correlation between asymmetric weight bearing and bone density, Shin and Kim[17] reported that bone density increased with greater weight bearing load, as the T score of the nonparetic side was higher than that of the paretic side in stroke patients with chronic hemiplegia. Liu et al.[18] measured bone density in the radius, femur, calcaneus, and lumbar vertebrae on the paretic and nonparetic sides of hemiplegic stroke patients at the time of hospital admission and discharge. A comparison of the results showed higher values on the nonparetic side. Many other studies have shown evidence of higher bone density on the nonparetic side than on the paretic side[19, 20]. Jorgensen et al.[21] measured patients' bone density regularly for a year after stroke to observe changes in bone density as the patients gradually recovered

Table 1. Demographic and clinical characteristics of the subjects (mean ± SD)

Variable	Stroke patients	Elderly
Age (years)	65.3 ± 8.5	61.4 ± 6.0
Height (cm)	156.5 ± 0.9	165.6 ± 6.0
Weight (kg)	58.2 ± 10.8	64.7 ± 7.5
BMI (kg/m^2)	23.9 ± 4.8	23.5 ± 1.6

BMI: body mass index

Table 3. Comparison of the changes in scores between the healthy elderly and stroke patients (mean ± SD)

BMD	Elderly	Stroke patients	
OI	0.59 ± 3.60	3.37 ± 3.74	**
T score	0.12 ± 0.71	0.67 ± 0.74	**
Z score	0.20 ± 0.94	0.67 ± 0.74	**

BMD: bone mineral density. **p<0.01

Table 2. Comparison of OI, *T* score, and *Z* score between the healthy elderly and the stroke patients (mean ± SD)

BMD	Elderly		Stroke patients		
	Right foot	Left foot	Nonparetic side	Paretic side	
OI	36.3 ± 5.3	35.7 ± 5.7	41.4 ± 5.1	38.1 ± 4.8	**
T score	−2.9 ± 0.98	−2.98 ± 1.0	−2.3 ± 1.0	−2.97 ± 0.96	**
Z score	−0.1 ± −0.98	−0.3 ± 0.9	−0.6 ± 1.2	−1.3 ± 1.2	**

BMD: bone mineral density. **p<0.01

their motor abilities. Patients who recovered their walking ability within 2 months after stroke showed less bone loss than those who did not. Kohrt et al.[22] and Unsi et al.[23] asserted that appropriate weight bearing would significantly increase bone density because suitable physical activity helps maintain or improve bone density. However, studies conducted by Young et al.[24] and Bauer et al.[25] showed conflicting results.

Studies that compared bone density in the upper and lower limbs between the dominant and nondominant sides revealed that the dominant hand showed better bone density than the nondominant hand, but the lower limb showed no difference or the opposite result[26–28].

In the present study, significant differences were found between the paretic and nonparetic sides of the stroke patients in terms OI, *T* score, and *Z* score, and the change in bone density was significant. Moreover, among the whole study population, the stroke patients showed the highest bone density values for the nonparetic side. The nonparetic side of stroke patients is exposed to greater weight bearing input and to excessive physical activity, causing it to gain greater bone density than that of the healthy population[16, 17]. Increased physical activity through functional recovery of hemiplegic patients can be considered important in preventing decreased bone density throughout the whole body.

The limitations to this study are as follows: First, as bone density could not be measured in patients before stroke, the actual extent of bone loss on the affected side could not be determined. Second, physical stimulation, including weight bearing, was the only factor taken into consideration, and other influencing factors such as changes in the sympathetic nerve system, smoking, and drinking were not considered. Third, the small number of subjects makes it difficult to generalize the results. Last, the criteria used for selecting subjects were age of ≥60 years and having lived in a sanatorium for at least 6 months. The number of subjects in the two groups differed because the subjects were compared under an identical environment. Therefore, future studies on reduced bone density due to decreased physical activity should completely exclude influences from changes in the sympathetic nerve system, smoking, drinking, and other risk factors, and examine a larger pool of subjects with an equal number of subjects in each group. In addition, measurement methods other than quantitative measurement should be used to observe the qualitative changes in bones, such as structural changes, bone replacement, and bone composition, in order to accurately evaluate the influence of reduced physical activity due to hemiplegia on bone density and to prevent osteoporosis in stroke patients.

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