Cross-Sectional and Longitudinal Studies on the Effect of Water Exercise in Controlling Bone Loss in Japanese Postmenopausal Women

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Summary The effects of water exercise, as a form of daily physical activity (water exercise in a warm water pool), on bone loss in healthy Japanese postmenopausal women have been cross-sectionally and longitudinally investigated from the viewpoint of preventing osteoporosis. In the cross-sectional study, the bone mineral density (BMD) of the lumbar spine (Z-score (%)) in the Veterans group (N=27), who had been exercising for 35.2 months on average, was significantly higher than that in the Newcomers (N=40), who had only begun to exercise 3 or 4 weeks before, and that in the Non-exercisers (N=30), serving as a control group. The rate of change in the BMD of the lumbar spine was -0.92%/year in the Non-exercisers (N=30), +1.55%/year in the Veterans (N=20), and +2.16%/year in the Newcomers (N=15), based on BMD Z-scores. In the Exercisers groups, it was found that the rate of change in the BMD showed a slight increase rather than a decrease irrespective of the duration of menopause. On the other hand, in the Non-exercisers group, the rate of change in the BMD decreased slightly. The results of questionnaires showed that the subjects' general awareness of health and fitness in daily life was enhanced after starting the water exercise program. These results suggest that consistently participating in water exercise is an important factor in preventing bone loss, and moreover, appears not only to indirectly improve awareness of daily physical activity but also to promote health and improve daily life.

Key Words water exercise, physical activity, prevention of osteoporosis, bone mineral density, dual energy X-ray absorptiometry, postmenopausal women

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Osteoporosis is a major public health problem in elderly people in Japan. While many academic studies have been conducted on the diagnosis, treatment, and prevention of osteoporosis, prevention is an essential, and often overlooked, aspect of this disease. Bone loss with age is influenced by multiple factors, such as heredity, estrogen deficiency, physical activity, nutrition, and life-style. It is well known that the postmenopausal state is considered to be a major risk for osteoporosis (1). Decreased physical activity has also been reported to be significantly related to the development of osteoporosis (2–4).

The first goal of osteoporosis prevention is to obtain a high peak bone mass at a young age. Determining how the decrease in bone mineral density (BMD) (5) can be effectively controlled is also essential. In women it is especially important to suppress the rapid bone loss caused by low estrogen after menopause (6, 7). Therefore, it is of great significance to take countermeasures against postmenopausal bone loss by improving various aspects of daily life, including diet and physical activity.

Ezawa reported previously that high dietary awareness and high physical activity are effective means of preventing osteoporosis (8). However, there have been no longitudinal studies as to the effects of exercise consisting of moderate physical activity on Japanese postmenopausal women. Accordingly, this study was designed to investigate the effects of water exercise, a form of moderate physical activity, on the BMD of postmenopausal women. It is difficult for elderly people to do weight-bearing exercises. They engage in fewer daily physical activities owing to their decreased physical capability and fitness or because of pain affecting the back, hip, knees, and other joints. Thus, water exercise (in a warm water pool) (9) is a suitable means by which the aged and non-swimmers can move their arms and legs easily and freely without burdening the joints, while maintaining buoyancy, with moderate physical exertion. The water exercises, which included walking, jumping, and light calisthenics in warm water (28–29°C), used in this study were done by middle-aged and elderly non-swimmers for the purpose of maintaining and promoting their health and preventing age-related deterioration. This exercise activity consists of a 10 min warm-up, 20 min of aerobic exercise and deep breathing, 10 min of swimming, and a 5 min cool-down. In this program, the level of activity has two Maximum Working Heart Rate peaks (approximately 120 beats/min) during the 45 min session which is carried out once a week.

We have examined whether water exercise improves daily life, including dietary and physical activity habits, in order to prevent the occurrence of osteoporosis in postmenopausal women. The exercises are aimed at increasing the quantity of daily physical activity. For this purpose, we have measured the bone mineral density of the lumbar spine (by DXA (dual X-ray absorptiometry), the first to fourth vertebrae (L1–L4)), and used a questionnaire to carry out a survey on nutrient intake and general awareness of health and fitness in daily life. Cross-sectional and longitudinal BMD studies were also conducted.
SUBJECTS AND METHODS

1. Subjects and methods. The subjects were 67 healthy Japanese postmenopausal women who had joined a water exercise class in a sports club in Tokyo in which they participated more than once a week. The control group consisted of 30 healthy Japanese postmenopausal women in Tokyo doing no particular regular exercise. There was thus a total of 97 healthy Japanese postmenopausal women without disease or therapy known to affect bone metabolism. They were divided into three groups: Non-exercisers (mean age: 60.13 ± 0.38 years, M ± SE), Newcomers who had just started to exercise (mean age: 63.68 ± 0.70 years), and Veterans (mean age: 64.26 ± 0.82 years). The exercise history of the Veterans was 35.2 months on average. The mean age at menopause of the Non-exercisers was 51.00 ± 0.43 years, of the Newcomers was 51.39 ± 0.50 years, and of the Veterans was 50.73 ± 0.54 years (M ± SE). Informed consent was obtained from all subjects. This investigation was carried out following the spirit of the Helsinki Declaration. Physical characteristics, the BMD of the lumbar spine (L1–L4, DXA method), nutrient intakes and general awareness using a questionnaire were studied.

Physical characteristics measured included body weight, height, body mass index (BMI), and body fat percentage (% fat) determination based on Bioelectrical Impedance Analysis. The BMD of the lumbar spine (L1–L4) was measured using dual X-ray absorptiometry (DXA) with Hologic’s QDR-1000. The coefficient of variation of our bone densitometer (DXA) was 0.52% during 1 year. The BMD values were expressed either in g/cm², or as a Z-score, based on the data from approximately 1,000 normal Japanese women aged 20–80 years (10), to indicate the deviation from the expected average values for sex- and age-matched normal subjects. The intakes of nutrients were estimated from 3-day dietary records. Each subject was given a dietary record-keeping form and kept a food diary for 3 days. During a follow-up interview, each subject’s BMD was measured and the dietary records were checked for completion. This data from the survey was analyzed, in terms of meals consumed for 3 days, using software for nutritive value calculation based on the 4th edition of the Japanese Food Composition Table (11) (WELLNESS by Top Business System, Okayama, Japan), and described in terms of a sufficiency rate for the requirements of individual nutrients, the average of the ratio of each nutrient requirement to that of each nutrient intake for each subject. General awareness of health and fitness in daily life was also investigated through questionnaires. In our longitudinal study, a second BMD measurement was carried out 1 year after the first in some of the subjects in the Exercisers groups (Veterans N=20, Newcomers N=15), and in all subjects in the Non-exercisers group (N=30).

2. Statistical methods. Student’s t-test was used to identify significant differences in BMD and anthropometric values among the groups. Analysis was performed by simple linear regression and by stepwise multiple regression using
High Quality Analysis Libraries for Business and Academic Users (Gendai-
sugakusha, Kyoto, Japan), A $p<0.05$ was considered statistically significant.

RESULTS

1. Cross-sectional study

Physical characteristics of the subjects, including age, height, body weight, body mass index (BMI), and body fat percentage (%) are shown in Table 1. There were no significant differences in height, body weight, body mass index, and body fat percentage (%) among the three groups. The exercisers group was, however, significantly older than the Non-exercisers group ($p<0.001$).

The intakes of primary nutrients were calculated on the basis of the sufficiency rates of the Japanese Recommended Dietary (RDA) Intake (12), as shown in Fig. 1. In the Exercisers group, the average intake of each nutrient was much greater than the RDA. On the other hand, the Non-exercisers group showed an insufficient iron intake, the average intake of the other nutrients being similar to the RDA.

The BMD of the lumbar spine was shown to be higher than the standard level for average Japanese women by DXA (based on data from Hamamatsu Medical College and Kawasaki Medical College (10)). Furthermore, the BMD of the Veterans group was higher than that of the other two groups (Veterans: $0.832 \pm 0.102 \text{g/cm}^2$, Newcomers: $0.766 \pm 0.117 \text{g/cm}^2$, Non-exercisers: $0.783 \pm 0.091 \text{g/cm}^2$, $\text{M} \pm \text{SD}$). In addition, as shown in Fig. 2, the BMD Z-scores of the Veterans group were significantly higher than those of the Newcomers and Non-exercisers groups (Newcomers: $p<0.05$, Non-exercisers: $p<0.001$). The correlation between the BMD and the anthropometric value was evaluated by simple linear regression analysis. The Non-exercisers group showed a significant positive correlation with body weight and the BMI ($r=0.440, p<0.015; r=0.440, p<0.015$), and of the two Exercisers groups, only the Newcomers showed a significant positive correlation with body weight ($r=0.444, p<0.004$, not shown in the table). There were no

| Group          | Non-exerciser | Water exercise |
|---------------|---------------|----------------|
|               |               | Newcomer       | Veteran        |
| Number of subjects | 30            | 40             | 27             |
| Age (year)    | 60.13±0.38    | 63.68±0.70**   | 64.26±0.82**   |
| Height (m)    | 1.53±0.01     | 1.53±0.01      | 1.53±0.01      |
| Weight (kg)   | 54.80±0.89    | 54.40±0.88     | 55.82±1.56     |
| BMI (kg/m²)   | 23.36±0.41    | 23.03±0.34     | 23.64±0.61     |
| Body fat (%)  | 30.36±1.12    | 30.19±0.81     | 30.96±1.46     |

The parameters were compared among the three groups using Student’s t-test (M±SE). **Significantly different from Non-exercisers group ($p<0.001$). No significant difference between Newcomers and Veterans groups.

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Fig. 1. The sufficiency rates of nutrients based on the 3-day survey in comparison to the Japanese Recommended Dietary Allowance (RDA). Intakes of all nutrients were higher than the RDA in the water exercisers groups. In the Non-exercisers group, however, iron was below the RDA (M±SE).

Fig. 2. The bone mineral density (BMD, Z%) of the lumbar spine (L1-L4) (M±SE). The data were compared among the three groups by Student’s t-test. In the Veterans group, BMD (Z%) was significantly higher than in the Newcomers and Non-exercisers groups.

significant correlations among these values in the Veterans group. Height, body weight, and the BMI were found to reflect the lumbar spine BMD in the Non-exercisers group and age was analyzed individually for those in the Exercisers groups by stepwise multiple regression analysis ($r^2=0.300, 0.089$, respectively, not shown in the table).

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2. **Longitudinal study**

Physical characteristics of the subjects, including 30 Non-exercisers, 15 Newcomers, and 20 Veterans, whose BMDs were measured after 1 year are shown in Table 2. In the longitudinal study, in either group, there was no significant difference in the anthropometric data except in the age of Non-exercisers group ($p < 0.05$), when compared with the previous year. The Exercisers were, however, significantly older than the Non-exercisers (Veterans: $p < 0.001$, Newcomers: $p < 0.05$), as was the case in the cross-sectional studies.

The rate of change in the BMD of the lumbar spine after 1 year was $-2.72\%$ ($0.783 \pm 0.017 \rightarrow 0.762 \pm 0.016$ g/cm², M ± SE) in the Non-exercisers group, $+0.75\%$ ($0.780 \pm 0.035 \rightarrow 0.784 \pm 0.032$ g/cm², M ± SE) in the Newcomers group, and $+0.27\%$ ($0.806 \pm 0.017 \rightarrow 0.810 \pm 0.021$ g/cm², M ± SE) in the Veterans group.

### Table 2. Physical characteristics of subjects in longitudinal study.

1) **Non-exercisers group (N=30)**

|                  | DXA-1        | DXA-2        |
|------------------|--------------|--------------|
| Age (year)       | 60.13±0.38***| 61.33±0.38   |
| Height (m)       | 1.533±0.01   | 1.529±0.01   |
| Weight (kg)      | 54.80±0.89   | 54.90±0.94   |
| BMI (kg/m²)      | 23.36±0.41   | 23.51±0.43   |
| Body fat (%)     | 30.36±1.12   | 31.86±1.08   |

2) **Newcomers group (N=15)**

|                  | DXA-1        | DXA-2        |
|------------------|--------------|--------------|
| Age (year)       | 62.33±0.99*  | 63.40±1.02   |
| Height (m)       | 1.526±0.01   | 1.529±0.01   |
| Weight (kg)      | 52.67±1.48   | 52.33±1.42   |
| BMI (kg/m²)      | 22.64±0.62   | 22.42±0.62   |
| Body fat (%)     | 30.17±1.44   | 30.51±1.68   |

3) **Veterans group (N=20)**

|                  | DXA-1        | DXA-2        |
|------------------|--------------|--------------|
| Age (year)       | 64.85±0.95** | 65.95±0.94   |
| Height (m)       | 1.537±0.01   | 1.535±0.01   |
| Weight (kg)      | 56.10±1.90   | 56.10±1.94   |
| BMI (kg/m²)      | 23.73±0.75   | 23.77±0.76   |
| Body fat (%)     | 31.84±1.83   | 33.57±1.63   |

No significant differences were noted, when compared with the previous year, in either group except in the age of Non-exercisers group ($p < 0.05$, M ± SE). There were no significant differences among groups except in age. DXA-1: the first BMD measurement; DXA-2: the second measurement was done 1 year after the first.

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*Significantly different from Non-exercisers group at the time of the DXA-1 measurement ($*p < 0.05$, **$p < 0.001$).
and the Z-scores were $-0.92$, $+2.16$, and $+1.55\%$, respectively, as shown in Fig. 3. The rates of change in the BMD Z-scores for each individual subject are shown in Fig. 4. The Non-exercisers group showed an obvious BMD decrease, whereas,

![Fig. 3](image1.png)

**Fig. 3.** The rate of change in the bone mineral density (BMD, Z%) of the lumbar spine (L1–L4) (M±SE), was measured using the same method as the cross-sectional study, 1 year after the initial measurement.

![Fig. 4](image2.png)

**Fig. 4.** The rates of change in the bone mineral density (BMD, Z%) of all individual subjects in the three groups.
the two Exercisers groups maintained their initial level or showed an increase.

As shown in Fig. 5, the general awareness survey \((N=48)\) showed improvements in life and health after starting the water exercise program. Many of them answered that their outlook on daily life had become more positive and pleasant and that their physical fitness had increased. They also reported being more aware of their health.

Fig. 5-1. Answers for the awareness survey concerning life in general: Changes in daily life \((N=48;\) plural answers). a: It has become more pleasant. b: I have become positive-minded. c: I walk a lot. d: I have become conscious of moving. e: There is no change.

Fig. 5-2. Answers for the awareness survey concerning life in general: Changes in health \((N=48;\) plural answers). a: My legs have become stronger. b: I have gained physical strength. c: Joint pains have disappeared. d: I have become conscious of my health. e: There is no change.
DISCUSSION

Recently, osteoporosis has become a major public health problem in Japan. Accordingly, it is essential to prevent, or at least delay, osteoporosis. The effects of exercise for the prevention of osteoporosis have been reported \((13-15)\), especially in postmenopausal women \((16-19)\), by a number of investigators. Orwoll et al. reported the results of measuring the BMDs of the radius and lumbar spine in 58 male swimmers aged 40 to 80, the values of which were significantly higher than those of the control group, and also tended to be higher than those of female swimmers \((20)\). On the other hand, it has been reported that the BMDs of swimmers were not significantly above the average control group value \((21, 22)\). It has not been clarified, as yet, what form of exercise is most suitable. An exercise program should be easy to continue and effective in preventing bone loss in middle-aged and elderly people, especially postmenopausal women. The critical factor is not the kind of exercise done but, rather, how to increase the quantity of physical activities suitable for this age and gender group. There is increasing evidence from intervention studies that moderate physical exercise in postmenopausal women may increase BMD or bone mass \((13)\) but further longterm studies are needed.

Therefore, in this study, the water exercise constituted moderate physical activity in daily life. Swimming was considered too vigorous. It has been reported that a moderate level of physical activity can be graded as follows: being on the feet 50-70% of the time or performing a regular set of exercises, such as jogging, walking, biking, and aerobics, for \(\geq 30\) min/day and \(\geq 2/\)week \((23)\). In this study, we employed water exercise with the aim of increasing the quantity of physical activities, and the effect of water exercise in controlling bone loss in postmenopausal women was investigated. The Veterans group, who had been doing water exercises for 35.2 months on average, showed higher lumbar spine BMD Z-scores than the Non-exercisers and Newcomers groups who had just started to exercise \((p<0.001, \ p<0.05)\).

It is assumed that bone mass is favorably affected by various factors such as the history of water exercise and awareness of life and health, in contrast to aging which tends to have a deleterious effect. In addition to these factors, the BMD of the Newcomers being higher than that of the Non-exercisers may be attributable to their being more positive about life and aware of their health than the Non-exercisers. Their voluntarily joining the class to maintain their health reflects this attitude.

In this longitudinal study, there were no significant differences in physical characteristics among any of the three groups. However, the BMD of the lumbar spine at the 1-year point showed a definite decrease in the Non-exercisers group.

It has already been reported that a decrease in BMD by \(1-2\%\) a year occurs in menopausal women \((2,3,24,25)\). The results of the Non-exercisers group in this
study were in accordance with such previous data. In the Exercisers groups, however, the BMD showed not a decrease, but rather maintenance or even an increase. The CV value of the lumbar spine phantom on the QDR-1000, a DXA used in this study, is 0.52%. Even when this volume is taken into consideration, the BMD had evidently decreased in the Non-exercisers group, while the water exercisers groups showed an improvement.

In postmenopausal women, as demonstrated in the Veterans group in this study, variables such as body weight, BMI and the BMD of the lumbar spine are not closely related. On the other hand, it does seem to be possible to increase BMD with moderate physical activity.

These results indicate that continuous water exercise has a suppressive effect on bone loss. It has been suggested that, in postmenopausal women, regular water exercises for the purpose of increasing the quantity of daily physical activities are effective in preventing bone loss and slowing the aging process and hence in preventing the occurrence of osteoporosis. Moreover, it was found to indirectly improve awareness of the state of health and to improve daily life.

The longterm effectiveness of water exercise should be evaluated by means of follow-up studies.

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