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EFFECT OF ONE-YEAR DUTY AS GOLF CADDIE ON AEROBIC CAPACITY AND BONE HEALTH IN PREMENOPAUSAL WOMEN

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Abstract

The purpose of this study was to determine whether intermittent, vigorous walking as a golf caddie for one year would increase aerobic work capacity ($\dot{V}O_2pk$) and bone health in healthy premenopausal women. Changes in 8 newcomer golf caddies (GC) were compared with 8 age-matched sedentary office workers (CO), age range: 34-47 yr. GC walked briskly and jogged ≈30% of the time, while covering 18 holes/day for 3-5 days/week. A digital pedometer recorded daily walking steps. GC averaged 20,487 steps/day while on duty (76 steps/min for 4.5 hr) and 6,374 steps/day during off-duty days, while CO averaged 5,388 steps/day. $\dot{V}O_2pk$, O_2pulse and $\dot{V}O_2$ at the double product break point as percent of $\dot{V}O_2pk$, measured on cycle ergometer, increased significantly over 12 months in GC but not in CO, with significant differences between groups. Calcaneal bone stiffness index measured by ultrasound densitometry, increased significantly by 5% in GC after 12 months, mostly in the last 6 months, with no change in CO. Bone mineral density (BMD) was measured by dual-energy X-ray absorptiometry in total hip and lumbar spine in 6 subjects from each group. Hip BMD increased significantly in GC after 12 months, significantly more than the small change in CO, and spine BMD showed similar, but nonsignificant trends, averaging 6 and 12 months. It is concluded that regular, brisk, intermittent walking for one year by healthy premenopausal women is sufficient exercise to increase cardiorespiratory fitness and improve calcaneal and hip bone health.

Key words: anaerobic threshold, bone density, oxygen consumption, walking

Introduction

The lower “quality of life” of the physically disabled elderly has become a serious health and social problem. Research over the past half century has led to the consensus that sedentary living leads to coronary artery disease and perhaps to some cancers, non-insulin-dependent diabetes mellitus and other health problems that can be prevented by habitual physical activity (1). Benefits of exercise in improving physical fitness should be especially emphasized in developed countries where life spans are extended. Physical fitness encompasses aerobic capacity (maximal oxygen uptake), strength, flexibility, balance and bone health. Many studies suggest that enhanced exercise capacity is associated with increased quality of life and longer survival (2).

Osteoporosis and osteoporotic fractures are a specific public health concern in developed countries. The age-standardized incidence of non-traumatic bone fractures has increased, with the most likely factor being decreased habitual and occupational physical activity that results in decreased bone elasticity and bone mineral density (BMD) (3,4). Weight-bearing physical activity in young premenopausal women may lower the risk of hip fractures when they become postmenopausal (5-7). Studies suggest that regular, high-impact, and high strain loadings are most effective to initiate bone development and long-term benefits in premenopausal women (8-12).

To preserve bone health in adults, the ACSM recommends moderate to high intensity weight-bearing endurance exercises, such as walking, jogging, jumping, stair-climbing or activities such as tennis, for 30-60 min/day, 3-5 days/week, plus resistance exercise of similar intensity for all major muscle groups 2-3 days/week (13). Resistance exercises are typically curtailed, especially in women, because for most non-athletes they involve special motivation, apparatus and instruction.

Brisk walking is a popular type of training exercise, especially among women, and has been recommended as an effective and safe way to increase physical fitness (14). Walking is accessible and socially acceptable for most women and therefore is frequently recommended by general health practitioners. Therefore, it seems important to determine whether intensive walking programs can serve as a partial substitute for the resistance exercises to provide the bone health benefits.

Results of walking studies in women are not consistent. A cross-sectional study by Uusi-Rasi et al. (15) found no significant differences in BMD, isometric strength and cardiorespiratory fitness between sedentary office workers and mail carriers. However, a 10-week intervention study comparing the effects of continuous vs. intermittent walking in sedentary middle-aged women (mean age: 44 yr) and age-matched controls demonstrated a greater $\dot{V}O_2$max and lactate threshold in both walking groups compared with controls (16). Another cross-sectional study with perimenopausal (mean age: 44 yr) and postmenopausal (mean age: 54 yr) golf caddies demonstrated greater calcaneal bone stiffness index (BSI) and leg and grip strength in caddies than in age-matched controls (17). Walking by golf caddies carrying golf clubs during rounds of play is not continuous, but intermittent and brisk, with many intervals of standing.

The purpose of this study was to examine the influence of one-year employment as a golf caddie, requiring long duration, brisk and non-continuous walking and some jogging, on aerobic fitness and bone health in middle-aged premenopausal women. We hypothesized that changes would be greater than those in a group of age matched, sedentary, premenopausal women.

Materials and methods

Subject

The participants were 16 Japanese women. Eight female golf caddies (37-44 yr) volunteered as subjects (GC) and eight female office workers (34-47 yr) served as a control group (CO). Office workers were selected from those that responded to an announcement about the study. Their history had to conform to that required, in terms of age, health status, nonsmoking history, test schedule availability, etc. The subjects in the CO group were not actively engaged in any organized physical activity programs. Golf caddies were also chosen from those that responded to a written advertisement about the study after being accepted for employment. None had prior experience as caddies. All subjects were premenopausal, as assessed by questionnaire. All participants were screened for bone abnormalities and chronic diseases and did not take medications known to affect cardiorespiratory and bone health. All were informed of all procedures and signed a consent form approved by the university human ethics committee before the study. Their age, physical characteristics and baseline bone measurements are shown in Table 1. There were no significant differences in any of these baseline measurements between groups.

Caddie duties

Caddies in this golf club do not walk with golfers as usual, by carrying shoulder golf bags, but remotely control a golf cart that carries only clubs, on a track for a number of golfers simultaneously. They walk the course, interspersed with going back and forth, by brisk walking and jogging, between golfers and cart, to deliver requested clubs for a group of golfers (3-4) playing together. These caddies worked 3-5 days/week and while on duty they would cover two 9-hole courses, each about 4 miles in length, taking about 2.25 hr for each, with a 30 min break between the two 9-hole courses.

Experimental design

All measurements for GC and CO subjects were made before (baseline) and after 6 and 12 months of caddie duties for GC. The subjects of both groups wore digital pedometers (Yamasa Co., Tokyo, Japan) on the waist daily during the year of the study. For all subjects the pedometer readings were taken in the morning when arising and when retiring for the night, with duty days noted for GC. All pedometer readings were made as total walking steps per day, with readings collected weekly in person or by telephone. In addition, GC also took readings at the beginning and end of their caddy activities on duty days. Prior to the start of the study and monthly thereafter, all subjects had their pedometers calibrated for counting accuracy by an investigator. An investigator verified the readings for the daily counts for the first week by comparing the detailed daily activity diaries with the counts. The compliance of recording pedometers was 100%.

Physiological testing

All subjects reported to the laboratory in the morning following an overnight fast. Each subject then performed

Table 1. *Mean age, physical characteristics and baseline measurements of subject groups*

	Age (yr)	Ht (cm)	Wt (kg)	BMI	%fat	BSI	hip BMD	spine BMD
GC	40.0	156.6	51.8	21.1	23.1	92.0	0.824	1.000
95% CI	1.7	1.8	4.6	1.6	2.0	5.1	0.066	0.073
CO	40.8	152.7	51.1	22.2	26.3	90.3	0.769	1.046
95% CI	3.5	5.3	4.3	3.2	4.9	4.6	0.060	0.041
p diff.	0.71	0.19	0.83	0.55	0.26	0.62	0.26	0.31

n=8 in each group, except for BMD where n=6
BMI: body mass index ($kg{\cdot}m^{-2}$)
BSI: bone stiffness index
BMD: bone mineral density ($g{\cdot}m^{-2}$)

a ramp exercise test to exhaustion. Exercise was performed on an electromagnetically braked cycle ergometer (Lode, Examiner, Groningen, The Netherlands) to determine peak oxygen consumption ($\dot{V}O_2pk$). The cycle ramp test was initiated following 2 min of zero-load pedaling, with the workload then increasing 10 W each minute, while maintaining a pedaling frequency of 50-60 rpm. The test was continued until subjects reached a point of voluntary exhaustion or could no longer maintain the pedaling frequency when the load was increased.

$\dot{V}O_2pk$

Gas exchange during the cycle test was recorded by an automated on-line gas analysis system (MetaMax system, Cortex Biophysik GmbH, Leipzig, Germany) calibrated with known gas mixtures. The $\dot{V}O_2pk$ was taken to be either (a) the $\dot{V}O_2$ value during the last minute prior to test termination due to exhaustion, if the highest value occurred in that minute, or (b) the value at an earlier interval if it subsequently declined. A respiratory exchange ratio (RER) value >1.10 was required to accept the $\dot{V}O_2pk$ value. The $\dot{V}O_2pk$ value in ml/min was divided by maximum heart rate (HR_{max}) to obtain O_2 pulse, the product of stroke volume and arteriovenous O_2 content difference.

Double product break point (DPBP)

Systolic and diastolic blood pressures and HR were measured by automated sphygmomanometer (CM-4001, Kyokko Bussan Co., Tokyo, Japan) and a 3-lead electrocardiogram before and during the cycle ergometer test at 15-s intervals. The double product (DP) is the product of HR and systolic blood pressure, estimating the work of the heart. The break point (BP) of this product (DPBP) is where the linear slope of DPBP/workload abruptly becomes steeper. This was quantified as the $\dot{V}O_2$ where it occurred, as a percentage of $\dot{V}O_2pk$. This point indicates an increase in cardiac demand, and has been found to be closely associated with the workload where blood lactate increases ("lactate threshold") in healthy subjects (18) and in cardiac patients (19,20). The continuously recorded HR and DP values were subsequently analyzed for DPBP by visual inspection.

Bone stiffness index (BSI) and bone mineral density (BMD)

Bone stiffness index (BSI)

Ultrasound has been used to estimate bone strength because it is dependent on bone structure and elasticity, which are related to bone health status. BSI decreases ≈1%/yr after the age of menopause in Japanese women (21). Ultrasonic measurements were made in the right os calcis using an Achilles ultrasound bone densitometer (Achilles, Lunar Co., Madison, WI) with the foot in a water bath at 37°C for 3 min. Measurements of the speed of sound (SOS) and the broadband ultrasound attenuation (BUA) are obtained through the trabecular region of the os calcis and BSI is calculated from the combined SOS and BUA values. The precision of the Achilles densitometer has been shown to be <2% in adults (22,23). The precision error in the present study was calculated from 32 measurements on two subjects over 50 days, with coefficients of variation CV for SOS, BUA and stiffness of 0.8, 2.5 and 3.2%, respectively.

BMD

Bone mineral density ($g{\cdot}cm^{-2}$) was measured in the lumbar spine (L1-L4) and in "total hip" using a Hologic QDR-1000W DXA scanner (Hologic Inc., Waltham, MA). All scans were performed at the same laboratory by the same technician to ensure consistent positioning. The average CV for 10 repeated measurements over one month at approximately 3-day intervals on two CO subjects was 0.4% for the hip and 1.6% for the spine. A previous study reported an average precision of 1.5% at these two sites (24). The data obtained from the DXA scanner was limited to 12 subjects (6 for each group) because of scheduling limitations.

Data analysis

Data are presented as means ± 1.96 x SEM (half of the 95% CI). Baseline differences in measurement values between groups were tested for significance (p=0.05) by two-sample t-tests assuming unequal variances. Differences in changes between the two groups in cardiorespiratory measurements from baseline to 6 months, baseline to 12 months and 6 to 12 months were similarly tested, using a Bonferroni adjustment for significance (0.05/3 = 0.017). Differences in changes between the groups in bone measurements over the same time periods were evaluated by analysis of covariance, using height and baseline values as control variables and the same significance levels. Effect size was estimated by Cohen's-d for differences between baseline and 12 months. Differences within each group between times were tested by paired t-tests with a similar Bonferroni adjustment (p = 0.017). Least squares linear regressions were use to obtain significance of correlations between baseline values and changes from baseline to 12 months for BSI and BMD and between baseline values and age and weight.

Results

GC averaged 20,487 (±403) steps/day of intermittent, vigorous walking during caddie duties, plus 3,080 (±305) steps/day during non-work time, and an average of 6,374 (±534) steps/day during off-duty days. CO averaged 5,388 (±388) steps/day, not significantly different than the number of steps by GC on off-duty

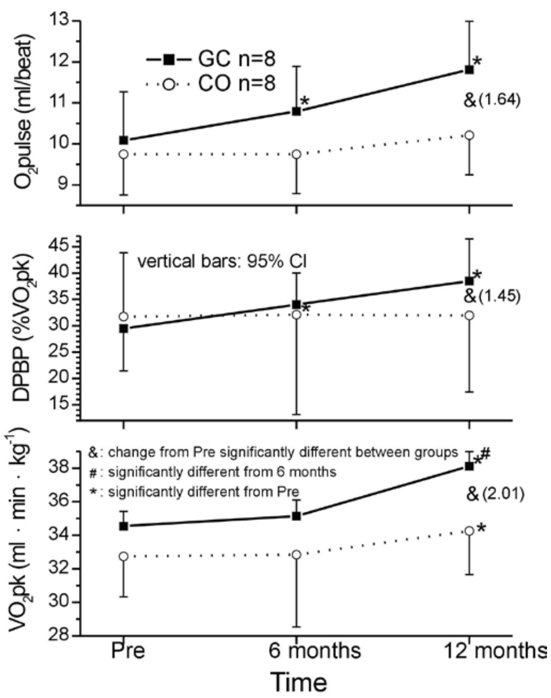

Fig. 1. *Mean maximal O_2 uptake ($\dot{V}O_2pk$), double product break point as a percentage of $\dot{V}O_2pk$ and O_2pulse in GC and CO groups (n=8) at baseline and after 6 and 12 months. Cohen's-d values are shown in parentheses for difference between group changes from baseline to 12 months.*

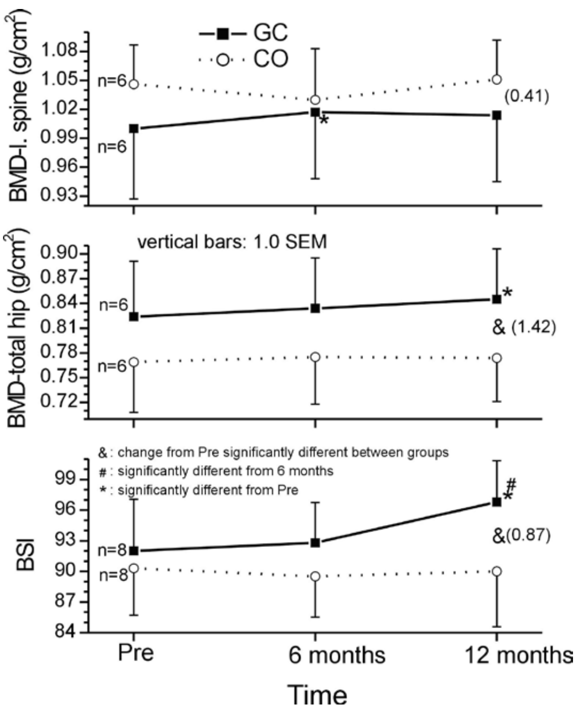

Fig. 2. *Calcaneal bone stiffness (BSI) and bone mineral density (BMD-g/cm²) of the total hip and lumbar spine in GC and CO groups at baseline and after 6 and 12 months. Cohen's-d values are shown in parentheses for difference between group changes from baseline to 12 months.*

days. Thus over the year GC walked ≈5.9 million steps, compared to ≈ 2.0 million for CO (p<0.001). Also, about 70% of the steps for GC on duty were brisk, with about 30% of those spent jogging. The average intensity of exercise while on duty for GC was 76 steps/min, about 12 times greater than during non-working days for CO and GC. Using the calibrations recently determined in 25 women aged 19-39 (25), this translates to a moderate work intensity of ≈3 METs, for 1/3 of the time on duty, and light intensity exercise for the remaining time.

Baseline $\dot{V}O_2$pk, as shown in Figure 1, was not significantly different between GC and CO. The small increase after 6 months was nearly significant for GC (p=0.059), with CO showing little change. There was a further significant increase in GC from 6 to 12 months. The increase over 12 months was significant in both groups, but 2.4 times and significantly greater in GC. The mean values for %$\dot{V}O_2$pk where the DPBP occurred were the same for the groups at baseline, but after 6 and 12 months it had increased by 5 and 9% in GC with almost no change in CO, resulting in a significantly greater rise in GC after 12 months. HR_{max} averaged 169 beats/min for both groups throughout the study, with no significant differences between them at any time and no significant changes from baseline to 12 months in either group. The O_2pulse in GC increased significantly after 6 and 12 months, but changed little in CO, resulting in a significantly greater change in GC than CO after 12 months. With the assumption of no change in stroke volume at maximal workload, this indicates a ≈10% greater O_2 extraction by GC than CO at $\dot{V}O_2$pk.

The BSI and BMD results are summarized in Figure 2. BSI increased significantly in GC from baseline to 12 months, with the increase being significantly greater than the change for CO. The BSI increase in GC after 12 months was inversely correlated with the baseline BSI (r = -0.79, p=0.020). The BMD of the hip increased significantly (0.021 g·cm^{-2} = 2.6%) after 12 months in GC and was significantly greater (p=0.015) than the change in CO (-0.006 g·cm^{-2} = -0.8%). The changes in BMD measurements in the lumbar spine after 6 months increased significantly in GC, but declined in CO and then both groups tended to return to baseline values. The average increase for 6 and 12 months was nonsignificantly greater for GC than CO by 2.1%. In GC the changes in BMD of the hip and spine over 12 months tended to be greater in those subjects with lower baseline values (r-values= -0.55 and –0.48), respectively, but not significantly so (p>0.26).

Correlations between age and baseline BMD measurements of the hip and spine for all subjects were not significant, with r-values of -0.50 and 0.00, respectively. Corresponding r-values for body weight were -0.09 and -0.45. Correlations between age and weight and baseline BSI (r = -0.28 and -0.19, respectively) were similarly not significant (all p-values >0.10).

Discussion

Aerobic work capacity

This study confirmed that regular, brisk, intermittent walking with jogging for one year was associated with improvements in aerobic fitness in premenopausal women, as measured by increased $\dot{V}O_2pk$, and power output required to elicit a given cardiac demand defined by DPBP. Murphy & Hardman (16) reported that $\dot{V}O_2max$ increased 8% in 24 women (mean age: 44 yr) after 10 weeks of brisk walking for 5 days/week for one daily 30 min session or three 10-min sessions. The walking pattern in the golf caddies in the present study is consistent with multiple bout sessions because there was a 30 min break between two 9-hole rounds of golf duties. Duncan, Gordon & Scott (26) demonstrated with an intervention study over 24 weeks in premenopausal women that $\dot{V}O_2max$ increased significantly over controls, with the increase being directly related to the speed of walking 5 km for 5 days/week. Cowan & Gregory (27) reported similar significant gains in estimated $\dot{V}O_2max$ in pre and postmenopausal women after a 9-week progressive walking program and Blumenthal et al. (28) demonstrated that 12 weeks of a walking-jogging program served to significantly increase $\dot{V}O_2pk$ by 18% in a group of perimenopausal women (mean age: 50 yr). Significant increases in $\dot{V}O_2max$ have also been reported after an 18-month program of walking, jogging, stair climbing and cycling for 50 min 3 days/week (29).

Other studies have demonstrated the DPBP occurring at higher power outputs after this type of exercise, suggesting a higher lactate threshold and improved cardiovascular fitness (16). Kobayashi et al. (30) reported that middle-aged women increased the DPBP after a 3 and 6 months of a continuous walking program. The finding of a greater increase in O_2 pulse in GC in the present study also supports the improvement in aerobic capacity, as it signifies an increase in systemic O_2 extraction, probably by improved matching of regional muscle blood flow to metabolic demand.

Because a cycle ergometer was used in the present study to assess the aerobic and cardiovascular changes from a long duration, brisk walking program, a training-specific effect on these beneficial changes was minimal. Thus, the overall increase in aerobic and cardiovascular fitness appears to have been induced primarily by the regular, intermittent walking during caddie activity, rather than walking when off-duty, because those steps were similar in number for both groups.

BSI and BMD changes

The BSI of the calcaneus was measured because of its sensitivity to applied forces during walking (31). Our results (Figure 2) show there was a significant increase over 12 months by GC compared with CO in BSI (5.5%), BMD of the hip (1.9%), and a nonsignificant increase for BMD of the lumbar spine (0.9%). This indicates a bone health benefit by long duration, brisk, intermittent walking by golf caddies, in comparison with the changes in the age-matched control group of healthy and relatively sedentary office workers. It was also observed in GC that those having the lowest baseline BSI and BMD tended to improve the most. This suggests that intervention study outcomes may well be dependent on the initial activity habits of the subjects. One previous cross-sectional study of women golf caddies reported that long-term (>2 yr) golf caddies (aged 40-49 yr) had significantly higher BSI values of the os calcis than controls (17). Their BSI values were 101.6 and 87.9 for the caddies and the controls, respectively, compared to our post-study values of 96.8 and 90.0. The results of this study differ somewhat from our previous investigation of calcaneal BSI changes in premenopausal women after a 6-month walking program, utilizing 10,000 steps/day (30). In that study, nonsignificant changes were found in BSI of the calcaneus. Since forces on the calcaneus are highly affected by the magnitude of the ground reaction force, apparently intermittent brisk walking, with some jogging on the soft grass of golf course, while carrying golf clubs, can be a sufficient additional stimulus to enhance calcaneal bone health. Daily walking steps (3-5 days/wk) in GC in the present study were twice that in the previous study and for twice as long. Vainionpaa et al. (31) reported a significant increase in BSI of the calcaneous after a 12-month exercise program in premenopausal women, provided that the ground reaction forces exceeded 2 G_z.

Higher activity levels in young women can apparently partially offset the normal bone loss with increasing age (7,32) and higher impact activity can be more effective in offsetting this loss (33,34). Several studies have reported significant increases in BMD of the femoral neck and lumbar vertebrae in premenopausal women after 6 to 24-month high impact loading exercise and resistance training (35-37). Another study in premenopausal women found that one year of training by combined walking and jumping exercise was more effective than walking only to maintain BMD of the lumbar and the proximal femur (38). It is also well documented that programs of weight-bearing exercises that impose high dynamic forces on the hip, such as jogging, volleyball and basketball, yield the most improvement in bone density (29,39).

In contrast, some cross-sectional studies showed no improvements in BMD after walking exercise in premenopausal women (12,15,40) or in peri-and postmenopausal women (41,42). These reports suggest that exercise programs need to be regular and monitored, and that the evaluation of past physical activity by questionnaire may be prone to inaccuracies when compliance and intensity are difficult to verify.

Walking on grass during golf rounding may be considered as low intensity skeletal loading in terms of the ground reaction force. A possible explanation for the improved BMD in golf caddies in the present study is that weight-bearing loading by long duration, brisk, intermittent walking and occasional jogging, while carrying a few golf clubs averaging 1.5 kg, can induce repeated short-lasting high strains and compressive forces on the hip that might have sufficient osteogenic effects on the lumbar spine and hip. It has been demonstrated in premenopausal women that walking at a faster pace positively benefits femoral neck BMD (31). Meta-analyses of randomized trials in both pre- and postmenopausal women have indicated positive effects of both impact and non-impact exercise programs on the lumbar spine and femoral neck, with impact exercise showing a greater benefit (43). The more vigorous walking for a longer duration probably accounts for the improvements of the femoral BMD by caddie duties in the present study. The significantly greater increases in BMD in the hip after 12 months and positive trends in the lumbar spine after 6 months in the present study indicate that for brisk walking, the duration (over at least 6-12 months) might be a major contributing factor in skeletal loading and musculoskeletal remodeling. In addition, the average working duties of caddies include more time per day standing than for CO. Apparently these particular caddie duties were of sufficient intensity to evoke changes that are consistent with higher impact activities referred to in other studies cited.

In conclusion, the present study suggests that brisk, intermittent walking for >6 months at an appropriate work site can increase aerobic and cardiovascular fitness and bone structure in the calcaneus and BMD in the proximal femur after peak bone development in women. This study is limited in the number of subjects and the age range that includes women in late premenopause, but it does support the hypothesis that activities of this type may serve to attenuate the normal reduction in bone mass with increasing age.

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Author's contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection