The Effects of Home-based Bench Step Exercise on Aerobic Capacity, Lower Extremity Power and Static Balance in Older Adults

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<Objective> To examine the effects of a twelve-week home-based bench step exercise program on aerobic capacity, lower extremity power and static balance in elderly subjects.

<Methods> Thirty-eight elderly men and women participated in this study (age: 75±4 years, mean±SD). The subjects were randomly assigned, according to the area in which they resided, into either the exercise group (EG: 11 men, 8 women) or the control group (CG: 14 men, 5 women). The EG performed a 12-week home-based bench step exercise program (7 sessions/week, 20-30 minutes/session, bench height 15.0-20cm). They recorded the length of exercise and their physical condition. Before and after the intervention a sub-maximum bench step test, a leg extension power test and a one-leg balance test with eyes open (balance test) were performed to assess the subjects’ aerobic capacity, as determined by the lactate threshold (LT), as well as lower extremity power and static balance ability. <Results> The LT (3.9(3.2, 4.9) vs. 5.4(4.8,5.6) METs; p<0.01) and leg extension power (7.1(6.2, 9.9) vs. 10.3(7.2, 13.7)watts/kg ; p<0.05) significantly increased while the balance test (9(4, 25) sec; p<0.1) also tended to increase in the EG. Conversely, these parameters did not significantly change in the CG (4.5(3.9, 5.1) vs. 4.9(4.3, 5.5) METs; 7.4(6.7, 12.5) vs. 8.1(7.3, 12.5) watts/kg, 17(8, 50) vs. 11(6, 20) sec, neither N.S.) Based on the diary data, the subjects in the EG exercised an average of 164±56 minutes/week for twelve weeks. <Conclusion> This study showed that a bench step exercise program effectively improved not only aerobic capacity but also lower extremity power and static balance ability in elderly subjects.

Keywords: bench step exercise, home-based, elderly, lactate threshold

1. Introduction

Aging is associated with various types of decline in physical fitness, such as aerobic capacity (Paterson, et al., 1999; Toth, et al., 1994), lower extremity power (Hakkinen and Hakkinen, 1991; Dawn, et al., 1994) and balance ability (Deforges, 1989). Thus, physical training programs specially designed for the elderly are needed, in view of the fact that a certain level of physical fitness is necessary for the elderly to live an independent life. With such training playing an important role in elderly health issues there is a need for training studies that examine the forms of exercise which elderly people can easily do, even at home, in order to make exercise a regular habit.

The most important factors regarding physical fitness for the elderly to maintain an independent life are aerobic capacity, lower extremity power...
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and balance ability. Numerous studies suggest that fit individuals have a lower risk of coronary heart disease and all-cause mortality than unfit individuals (Blair, et al., 1989; Williams, 2001). In addition, there is a decline in the occurrence of physiological impairments, such as muscle weakness and balance ability (Caerter, et al., 2001). Furthermore, impaired muscle power resulting in muscle weakness may have an influence on the incidence of disability (Foldvari, et al., 2000). Although it is conceivable that skeletal muscle cannot adapt optimally to two contradictory training stimuli, such as aerobic capacity and anaerobic power, when they are simultaneously imposed (Sale, et al., 1990), some forms of endurance training do, in fact, increase strength (Rosser, et al., 1986; Moroz and Houston, 1987) and muscle fiber size (Gollnick, et al., 1973) as well as aerobic capacity.

Bench step exercise has become a popular treatment mode in cardiovascular fitness and knee rehabilitation programs. Using a 20cm step height, a previous study (Zimmermann, et al., 1994) on EMG (electromyographic) activity suggested that such stepping exercise is recommended for strengthening the lower extremity muscle groups. In fact, Bean, et al., (2002) reported that weighted stair climbing exercise improved leg-press power in mobility-limited older people, while walking exercise did not bring about an improvement. Also, their subjects trained under the direct supervision of a research assistant. We herein propose a new home-based physical training program for the elderly. Note that this is a physical training program that can be performed at home by the elderly with ease and safety, if we can prescribe the appropriate intensity. We hypothesized that bench step exercise could enhance not only aerobic capacity but also lower extremity power. In addition, bench step exercise requires that the subject stand on one foot and sustain his or her own weight with that foot, so it has the potential to enhance balance ability.

The objectives of this research study are as follows: to find out the best way to encourage elderly subjects to develop the habit of regular exercise on a daily basis and to examine the effects of physical training programs on the elderly in terms of aerobic capacity, lower extremity power and the ability to maintain static balance. We chose the lactate threshold as the training intensity, since it has been proven to be an effective measurement guideline that is safe and easy to perform.

2. Methods

2.1. Subjects

Thirty-eight elderly people (25 men, 13 women) participated in this study. They were put into two groups, namely the Exercise Group (EG) and the Control Group (CG), depending on where they lived. None of them had engaged in any regular exercise program prior to this study. Also, the subjects in the CG were asked to maintain a normal lifestyle during the study. The experimental procedure was approved by the ethics committee of Fukuoka University. We obtained written informed consent from all participants.

2.2. Assessments

All participants had their height and weight measured, and their BMI computed, prior to the twelve-week intervention period. The following tests were administered for the following purposes before and after the twelve-week intervention period:

1) A sub-maximal graded bench stepping test was carried out to determine each individual’s lactate threshold, which was then used as the person’s aerobic capacity index. A twenty centimeter bench height was chosen for most subjects, but a fifteen centimeter height was used for some frail subjects. The step cadence was initially set at forty steps/minute and then it was increased every four minutes by ten steps/minute with a two minute rest interval until the blood lactate concentration (LA) reached four mmol/l and a perceived exertion rate (RPE) of seventeen. The Heart Rate (HR) was determined at rest and during the last thirty seconds of each stage. Blood samples were obtained from the earlobe to determine the LA, while the RPE was obtained both during rest and just after the completion of each work stage. The HR was measured using an HR monitor (Accurex Plus, Polar Electric, Finland). The LA was measured with a portable lactate measuring device (Lactate Pro, Arkray, Japan). The RPE was obtained using the fifteen-point Borg category scale (Borg 1982). The first breaking point of the LA was assessed by five well trained technicians and the highest and lowest values were excluded. The mean of three values was
accepted for the LT. Exercise intensity was converted to METs from the step height and the number of ascents/minute according to the formula described in the ACSM guidelines for exercise tests and prescription (ACSM, 2000).

b) A leg extension power test (Hirano, et al., 1994) was carried out to assess each individual’s lower extremity power. Leg extension power output was measured (Anaeropress 3500, Combi, Japan). Subjects sat on a seat and explosively pushed a foot plate in a horizontal direction, to which the body mass of each subject was applied as a resistance. The power was measured five times and the maximal value was then used for the analysis.

c) A one-leg-balance-with-eyes-open test (Islam, 2004) was carried out to assess each person’s static balance ability. Participants stood on their preferred foot while resting their hands at waist level, then raised the other foot approximately ten centimeters off the floor. Balance was scored as the number of seconds for which the foot was kept raised or until the subject’s balance was lost. The test was performed twice, and the higher value was used for analysis.

2.3. The Exercise Program

The exercise program consisted of a bench step exercise program that was performed daily at home for twelve weeks and a ninety-minute weekly exercise session in which only the EG took part. The exercise sessions were conducted at a community welfare center by an exercise leader. Each participant’s exercise intensity was prescribed in accordance with the height of the bench step and the frequency of the ascents and descents, as determined by the participant’s lactate threshold. The exercise intensity was readjusted for the latter six weeks. Participants were encouraged to do the bench step exercise three times daily for ten to twenty minutes prior to each meal or to engage in this exercise for a total of 140 minutes or more every week. Participants were asked to record the length of their training at home and their physical condition on a daily basis. The weekly ninety-minute exercise session consisted of:

1) Warming-up exercises for 10 or so minutes
2) Simple hand games for 10 or so minutes
3) Bench step exercise for 10 minutes
4) Approximately a 15-minute break
5) Recreation for about 20 minutes
6) Stretching exercises for 10 or so minutes
7) Bench step exercise for 10 minutes
8) Warming down exercises

2.4. Special Features and Other Characteristics of the Exercise Program

A cassette tape of music with a rhythmic beat was lent to EG participants free of charge to help them carry out the exercise program more easily. Fixed height walking frames were also lent to the subjects as supportive devices to those suffering from any dysfunctions of the lower extremities. Participants were advised to exercise prior to meals. The training diary completed daily by the participants was used by the exercise leader as a means of giving advice and other messages so that the participants could remain highly motivated.

2.5. Statistical Analysis

In Table 1 the data is expressed as the mean value and standard deviation (mean (standard deviation)) and in Table 2 it is expressed as the median value and the 25% and 75% values (median value (25%, 75%)). Since the sample size is small, all statistical analysis has been conducted using non-parametric analysis. The Mann-Whitney test was used to assess any differences in the group comparisons at baseline and during the observation periods. The Wilcoxon test was used to assess any within-group changes for the training and control groups. In all instances, the .05 level of probability was used to determine the statistical significance.

3. Results and Findings

The following is an outline of subjects’ participation levels and the amount of exercise they actually performed. Of the nineteen subjects in the EG and the nineteen in the CG, seventeen and fourteen remained active participants throughout the study in their respective groups. The attributes of these participants are shown in Table 1. There were no significant differences between the groups in terms of vital statistics and physical fitness at baseline (see Table 2). The average rate of participation in the weekly ninety-minute exercise session in the EG was 97%. The average length of time spent on physical
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Table 1  Attributes of the Subjects

<table>
<thead>
<tr>
<th></th>
<th>Exercise Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects (men/women)</td>
<td>17 (10/7)</td>
<td>14 (10/4)</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>75 (4)</td>
<td>74 (3)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158.2 (7.8)</td>
<td>155.1 (7.8)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.1 (13.7)</td>
<td>57.3 (11.7)</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>24.3 (4.2)</td>
<td>23.7 (3.7)</td>
</tr>
</tbody>
</table>

Note that each figure given in Table 1 is the mean value and that the standard deviations are represented by the numbers in parentheses. Note also that there were no significant differences between the two groups of participants regarding any of the factors considered.

Table 2  Changes in Physical Assessment Values

<table>
<thead>
<tr>
<th></th>
<th>Exercise Group</th>
<th></th>
<th>Control Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior to</td>
<td>12-wk</td>
<td>Prior to</td>
<td>12-wk</td>
</tr>
<tr>
<td></td>
<td>Intervention</td>
<td>Intervention</td>
<td>Intervention</td>
<td>Intervention</td>
</tr>
<tr>
<td>METs@LT</td>
<td>3.9 (3.2, 4.9)</td>
<td>5.4 (4.8, 5.6)</td>
<td>4.5 (3.9, 5.1)</td>
<td>4.9 (4.3, 5.5)</td>
</tr>
<tr>
<td>Leg Extension Power (watts/kg)</td>
<td>7.1 (6.2, 9.9)</td>
<td>10.3 (7.2, 13.7)</td>
<td>7.4 (6.7, 12.5)</td>
<td>8.1 (7.3, 12.5)</td>
</tr>
<tr>
<td>Balance test value (sec)</td>
<td>9 (4, 25)</td>
<td>16 (6, 35)</td>
<td>17 (8, 50)</td>
<td>11 (6, 20)</td>
</tr>
</tbody>
</table>

Note that each figure given in Table 2 is the median value and that 25% and 75% values are represented by the numbers in parentheses.

METs - Metabolic equivalents, estimated by means of the following equation:

\[
\text{METs} = (0.2 \times \text{stepping rate} + 1.33 \times 1.8 \times \text{step height} \times \text{stepping rate})/3.5)/3.5 
\]

(training by the EG participants for the duration of the twelve-week period was 164±56 minutes per week and 65% of them achieved our recommended training quantity.

Significant improvements were observed in the lactate threshold and the leg extension power of the EG participants. In addition the EG participants’ static balance also tended to improve (see Table 2). No significant change was observed in any of the three items regarding the physical fitness of the CG participants (see Table 2). Compared with the CG participants, the EG participants show marked increases in their lactate threshold and balance values, while their leg extension power also tended to increase (Figure 1).

4. Discussion

The primary findings of this study were that moderate bench step exercise training, performed at home, led to great improvements in leg extension power as well as lactate threshold in elderly people.

There are several potential reasons for the success achieved by the bench step exercise program. First, owing to the advice and encouragement of the exercise leader, based on the training diary completed daily by the participants, as well as the weekly exercise and recreational activity, high levels of participation and compliance to the training protocol were achieved. The use of the cassette tape lent to all participants, which included ten minutes of music with a rhythmic beat and also announced breaks, helped them continue the exercise.
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Program, heightened their interest, and thus resulted in a good level of adherence. Furthermore, fixed height walking frames were also lent to subjects as supportive devices for the frail or those suffering from dysfunctions of the lower extremities. This too may have contributed to the high participation rate in this study. However these factors are important with regard to exercise training for the elderly, they are not based on scientific inspection. Therefore future studies should investigate these factors.

As a result, the average length of time spent in physical training for the duration of the twelve-week period was 164±56 minutes per week, thus exceeding the duration recommended by the American College of Sports Medicine (ACSM, 2000) to improve aerobic capacity. The results for duration/week were similar to or exceeded those of previous reports shown to elicit an improvement in the aerobic capacity in the elderly with the training intensity at or below the LT. Belman and Gaesser (1997) showed that a 12% increase in the LT can be achieved with sub-LT exercise training of four days per week of thirty minutes per session for eight weeks. Motoyama, et al., (1995) showed that exercise training that is conducted three to six times per week at the LT intensity could increase the mean change rate by 10.5%. In addition to an increase in the lactate threshold, an improvement in leg extension power was observed in this study. The improvement in leg extension power seen in this study may be explained by the specific training mode. The present findings correlate with those of previous reports that showed a significant increase in leg press power in mobility-limited older people through stair climbing training while wearing a weight vest (Bean, et al., 2002). The present study showed that even without wearing a weighted vest, a bench step exercise program could increase leg extension power. The finding that endurance training alone can elicit an increase in anaerobic fitness correlates with the findings of a study done by Delecluse, et al., (2003), who reported that fitness sessions consisting exclusively of endurance training were as effective in increasing knee extension strength as combined endurance and resistance training.

The EMG activity of the gluteus maximus

\[\text{Figure 1} \quad \text{A comparison of substantive changes in physical fitness between EG and CG}\]
and vastus medialis, which are responsible for leg extension, was reported during stair stepping exercise (Zimmerman, et al., 1994), which is a similar training mode to that of the bench step. The report showed the mean EMG activity to be 20–53% of the maximum voluntary isometric contraction while exercising with a 20.3cm bench height on a stepping ergometer at cadences of 35, 60, 95 steps/minute in young adults (Zimmerman, et al., 1994). The increase in the mean EMG activity for these muscles from 35 to 95 steps per minute was found to be significant. As a result the mean EMG activities in the vastus medialis at 95 steps per minute exceeded 50% of the maximum voluntary isometric contraction. We obtained similar results during a bench step exercise with a 20cm height in young male students (unpublished). In this study, bench heights were varied between fifteen and twenty centimeters because of different individual LT levels. Since we used the 20 centimeter height as much as possible with a different cadence, most of the subjects used the 20 centimeter height, especially in the latter six weeks of the study. The average and standard deviation in bench height and cadence were 18.5 ±2.6 cm and 91±10 beats per minute respectively. Since muscle strength decreases with aging, the EMG activity of the maximum voluntary isometric contraction would be at a much higher percentage in elderly people. So it would be adequate to produce a significant change in leg extension power.

In conclusion, a simple home-based moderate intensity bench step exercise program was found to greatly increase aerobic power and leg extension power in elderly subjects. These findings correlate with those of several previous studies in which aerobic exercise training was shown to increase power and aerobic power (Roser, et al., 1986; Moroz and Houston, 1987; Bean, et al., 2002). As suggested by Moroz, et al. (1987), the training mode is thus considered to play an important role in increasing muscle power and strength. Bench step training at the lactate threshold is one of the optimal health oriented exercise programs for the elderly to improve both their neuromuscular strength and cardiovascular health.

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References


