Effect of 6-Month Walking and Stair-Climbing Exercise Program and Walking with Blood Flow Restriction on Body Composition and Hemoglobin A1c Levels in Elderly People

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Objective: This study aimed to evaluate the effects of a long-term training program combining increased physical activity and walking with blood flow restriction (BFR) on the body composition and glycated hemoglobin (HbA1c) levels in elderly subjects.

Methods: A total of 13 subjects (age, 67 ± 1 years) were assigned to the walking and stair-climbing (WS) group (6 men) or the WS and BFR-walk (BFR) group (5 men and 2 women). Both groups were instructed to complete walking sessions of more than 30 min, at a self-selected, faster pace than usual, and to climb more than 5 flights of stairs per day, for at least four days per week. In addition, the BFR group completed a 20-min treadmill walking session on a weekly basis, for 6 months, at a pre-determined exercise intensity of 70-85% of the age-predicted maximum heart rate and with BFR of 100-120 mmHg applied to both thighs. The measured outcome variables included height, body weight (BW), waist circumference (WC), body mass index (BMI), muscle mass, fat mass, body fat (%Fat), and HbA1c levels, measured at baseline, at the 3-month midpoint of the program, and at the 6-month endpoint.

Results: After the 6-month intervention, the BW, WC, BMI, fat mass, %fat, and HbA1c levels were decreased compared to baseline in both the WS and BFR groups (p<0.01), with the muscle mass increasing in both groups (p<0.05).

Conclusions: A 6-month walking and stair-climbing exercise program was effective in improving body composition and HbA1c levels in elderly subjects, with no added benefits of BFR.

Key words: blood flow restriction, exercise intervention, HbA1c, stair climbing, walking

Introduction

Obesity and leading an age-related sedentary lifestyle are recognized as major risk factors for the development of several chronic diseases, including type-2 diabetes, cardiovascular diseases, and cancer1)-5). Meanwhile, age-related reduction in skeletal muscle mass may lead to increased risks of impaired glucose control (glycated hemoglobin; HbA1c) and insulin resistance, as well as various other diseases6). Additionally, the consequent decreases in the lower limb muscles lead to reduced ambulatory ability.

Therefore, strategies to improve or maintain body composition across one’s lifespan are important factors for the general health of elderly people.

Many studies have reported that regular exercise and increased physical activity can improve body composition7)-8). To improve physical fitness and body composition, the American College of Sports Medicine recommends performing physical activity three to five times each week, for 20 to 60 minutes at a time9). As elderly individuals often have multiple diseases that affect their activities of daily life and quality of life, it is important to develop...
practical exercise programs that are effective in increasing muscle mass and/or reducing body fat and obesity-related health risks. Walking is the most popular physical activity for middle-aged and older people; it requires minimal equipment, can be done at any time of day, and can be performed at a self-selected pace. Although walking can produce a significant increase in muscle mass, but the effect is minimal. Evidence indicates that changes in muscle mass require a higher training intensity. A common example of daily physical activity that has higher exercise intensity than walking is stair-climbing. Stair climbing seems to contribute to improving glucose control in elderly people with type 2 diabetes. Therefore, a combination of walking and stair-climbing may be more effective for improving body composition (i.e. increasing muscle mass and reducing fat mass) and glucose control in elderly people, compared to only walking. However, the efficacy of this combination on body composition and glucose control in elderly individuals has yet to be evaluated.

Numerous peer-reviewed papers over the past decade have demonstrated that blood flow restriction (BFR) to working muscles during walking enhances the hypertrophic effects thereof. Abe et al. showed that the mean VO₂ was higher in the latter half of a treadmill walking with BFR (5 x 2-min) compared to normal walking at the same speed (75 m/min). The authors speculated this increase in VO₂ may be related to an elevation of the serum growth hormone concentration after a single bout of BFR walking. Further, more recent evidence indicated a greater net metabolic cost (VO₂, VE, and VE/VO₂) in 5 x 3-min bouts of treadmill walking with BFR compared to normal walking. Based on these data, BFR during walking could enhance the effects of normal walking on both increasing muscle mass and decreasing fat mass, which contributes to improving or maintaining body composition and glucose control in elderly people.

With this in mind, our study aimed to evaluate the effects of a long-term training program combining increased physical activity and walking with BFR on the body composition and HbA1c levels in elderly subjects. HbA1c is the most widely used indicator of glucose control in individuals, and can be used to assess overall metabolic control over the preceding 6-8 weeks.

Materials and methods

1. Subjects
Twenty-three individuals, aged > 65 years, who had not undergone resistance training for at least 1 year prior to the start of the study, volunteered to participate in this study and provided signed informed consent. The subjects were allocated to one of two groups: the walking and stair-climbing group with limb BFR (BFR group, 6 men and 3 women) or the walking and stair-climbing only group (WS group, 12 men and 2 women). This study was approved by the Ethics Committee of the Juntendo University (Japan).

2. Exercise program intervention
Approximately one week prior to the start of the exercise program, the subjects completed laboratory-based measurements of body composition and HbA1c. All subjects were instructed to walk at a self-selected, faster pace than usual for 30 min consecutively, more than 4 days per week in the WS group and more than 3 days per week in the BFR group, and to climb more than 5 flights of stairs per day, on 4 or more days per week. In addition, subjects in the BFR group attended the lab once a week to complete a 20-min bout of treadmill walking with applied BFR.

3. Blood flow restriction
BFR (100-120 mmHg) was performed on a weekly basis over the 6-month duration of the program. BFR was applied during a 20-min bout of treadmill walking at a pre-determined exercise intensity of 70-85% of the age-predicted maximum heart rate (220 - age). During the BFR-walking session, 105-mm wide nylon cuffs (MT-870 Digital Tourniquet; Mizuho, Tokyo, Japan) were applied tightly around the bilateral thighs, as arterial occlusion pressure is largely influenced by thigh circumference, the applied pressure value was calculated for each subject based on the circumference of the right thigh, measured at 33% of the distance from the inguinal crease to the top of the patella: 100 mmHg for a circumference < 50 cm; 120 mmHg for a circumference of 51 to 55 cm. The cuff air pressure was released immediately upon completion of each walking bout.
4. Body composition and HbA1c measurements

Height, body weight (BW), waist circumference (WC), body mass index (BMI), muscle mass, fat mass, and percent of body fat (%Fat) were measured for all subjects at baseline (i.e., approximately one week prior to the start of the program), at the 3-month midpoint of the program, and at the termination of the 6-month program. Laboratory-based measurements were performed at approximately the same time of day for all measurement time points to control for diurnal effects on the outcome variables. Body composition was determined by bioelectrical impedance analysis using a body composition analyzer (InBody720; Biospace, Centennial, CO, USA). Blood tests for HbA1c levels were performed after a minimum of 4 hours of fasting.

5. Statistical analysis

The data obtained over the 6-month period were analyzed using two-way repeated-measures analysis of variance (ANOVA; Condition × Time). In the current study, subjects who had carried out more than 80% of both the walking and stair-climbing programs were included in the final analysis (WS: n=6, 6 men; BFR: n=7, 5 men and 2 women). Statistical significance was set at p < 0.05. All analyses were performed using Prism software (ver. 6.0; GraphPad Software Inc., San Diego, CA, USA). Data are presented as the mean ± standard error.

Results

1. Body weight and body composition

Changes in body weight and composition over the 6-month exercise program are reported in Table-1. At baseline, there were no significant differences in weight, WC, BMI muscle mass, fat mass, and %Fat. For both groups, main effects of exercise time on decreasing body weight, WC, fat mass, %Fat, and BMI (p < 0.01), as well as on increasing muscle mass (p<0.05), were observed.

2. Glycated hemoglobin (HbA1c) levels

Changes in the HbA1c levels over the 6-month exercise program are shown in Figure-1. For both groups, there was a main effect of exercise time on lowering the HbA1c levels (p<0.01).

3. Training time and frequency

Over the study period, subjects in the BFR group walked on average 46.0 ± 5.2 min per day, 4.2 ± 0.5 days per week (1-3 months, 45.0 ± 5.2 min per day, 4.7 ± 0.4 days per week; 4-6 months, 47.3 ± 5.4 min per day, 3.8 ± 0.6 days per week), compared to 64.5 ± 10.5 min per day, 4.6 ± 0.5 days per week for the WS group (1-3 months, 61.9 ± 11.2 min per day, 4.9 ± 0.6 days per week; 4-6 months, 72.0 ± 13.6 min per day, 4.3 ± 0.6 days per week). In addition, subjects in the BFR group completed 20 min of treadmill walking with BFR per week. There were no significant differences in the training time and frequency between the groups.

Subjects in the WS group completed a greater absolute number of stairs climbs, with an average 9.1 ± 2.5 flights of stairs completed per day over 4.9 ± 0.5 days per week (1-3 months, 8.7 ± 2.3 flights per day over 5.3 ± 0.7 days per week; 4-6 months, 9.6 ± 2.7 flights per day over 4.4 ± 0.7 days per week), compared to 6.9 ± 0.7 flights of

Table-1  Effects of 6-months blood flow restriction-walking or control program of physical exercise on metabolic parameters

| Variable     | WS (n=6, 6 men) | BFR (n=7, 5 men and 2 women) | 2-way ANOVA (p) |
|--------------|----------------|-----------------------------|----------------|
|              | Baseline 3M 6M| Baseline 3M 6M               | Time Condition Interaction |
| Weight (kg)  | 66.9±3.0 66.4±2.4 65.5±2.4 | 64.4±2.3 64.3±2.4 63.1±2.2 | <0.01 0.511 0.910 |
| WC (cm)      | 89.1±2.1 86.1±2.1 87.4±2.3 | 88.5±3.1 87.8±3.3 87.0±3.4 | <0.01 0.956 <0.05 |
| BMI (kg/m²)  | 24.7±0.7 24.6±0.6 24.2±0.7 | 23.6±0.8 23.5±0.8 23.1±0.9 | <0.01 0.327 0.949 |
| Muscle mass (kg) | 27.6±1.1 28.2±1.0 27.9±1.0 | 25.6±1.3 25.8±1.2 25.8±1.2 | <0.05 0.215 0.355 |
| Fat mass (kg) | 17.3±1.4 15.6±1.3 15.2±1.2 | 17.7±2.0 17.2±2.3 16.1±2.3 | <0.01 0.718 0.312 |
| % Fat (%)    | 25.6±1.1 23.4±1.5 23.1±1.2 | 27.4±2.9 26.5±3.3 25.1±3.3 | <0.01 0.529 0.299 |

Two-factor repeated-measured analysis of covariance was used for the analysis. Values are presented as the mean ± standard error; WS, the walking and stair-climbing group, in which participants performed increased physical activity only (6 men); BFR, the walking group with limb blood flow restriction (BFR) (5 men and 2 women). No significant differences among the groups were observed with regard to any variables at baseline. WC: waist circumference, BMI: body mass index, %Fat: percent of body fat.
stairs completed per day, over 4.5 ± 0.5 days, by subjects in the BFR group (1-3 months, 6.7 ± 0.7 flights per day over 5.1 ± 0.4 days per week; 4-6 months, 7.3 ± 0.8 flights per day over 3.8 ± 0.6 days per week). There were no significant differences in the number of stairs climbs and the frequency between the groups.

Discussion

In this study, we demonstrated that our 6-month exercise program yielded significant improvements in body weight (-1.4 kg), body compositions (-1.6 cm for WC; -0.53 kg/m² for BMI; + 0.25 kg for muscle mass; -1.9 kg for fat mass; and -2.38% for %fat), and HbA1c levels (-0.19%) in elderly people. These data are in line with previous studies reporting that increased physical activity significantly decreased BW and WC. Our data indicate that the combination of increased physical activity due to higher intensity exercise (walk fast and stair climbing) was effective in improving body composition of elderly people, increasing muscle mass and decreasing fat mass.

A meta-analysis by Boulé et al. demonstrated that reductions in the HbA1c levels following a program of aerobic training in diabetic patients were better predicted by exercise intensity than exercise volume. Our exercise program consisted of 4-5 bouts of > 40 min of walking per week, performed at a pace higher than the usual self-selected pace, and climbing of more than 5 flights of stairs per day. Takaishi et al. demonstrated that a short bout of stair climbing/descending exercise (12 sets of 21 steps, 18 cm in height) may be a useful method for improving glycemic control, compared with normal walking after a meal, in older people with type 2 diabetes. Therefore, a combination of walking and stair-climbing may be effective for improving HbA1c levels in elderly people, as compared to only walking. The importance of exercise intensity on glucose control is supported by previous studies that have demonstrated that a combination of aerobic and resistance training is more effective in reducing HbA1c levels than aerobic training or resistance training alone.

Although the reduction in the HbA1c level was small in our study compared with in previous studies that performed a combination of aerobic and resistance training, we nonetheless consider that the magnitude of decrease achieved might be effective for reducing the risk of metabolic syndrome, cardiovascular disease, and other age-related diseases.

Recent research has provided evidence of the effects of BFR applied during walking on increasing muscle mass, oxygen consumption during and post-walking, energy expenditure, and the net metabolic cost of walking in healthy young adults. These data support the notion that walking combined with BFR is more effective for improving the BW, body composition, and HbA1c levels in elderly people than normal walking. However, our BFR walking intervention did not further enhance the effects of the WS program on body composition and HbA1c levels in the present study. This may be related to the fact that the body weight, BMI, and WC of the subjects in the BFR group tended to be lower than those in the subjects in the WS group at baseline, which could have masked the synergistic effect of BFR. It is also possible that only one session of BFR walking per week was insufficient to induce changes in the body weight and composition, as well as in the HbA1c level. The influence of exercise with BFR on obesity and overweight are likely to be multifactorial in nature, and the optimal frequency and intensity have yet to be determined.

The limitations of our study need to be noted when interpreting our results. First and foremost, we did not control for medication use, with the subjects adhering to their usual prescriptions, although we instructed the subjects to not change their medication regimens during the study. As a number of different drugs were used by our subjects, including antihypertensives, antidiabetic...
drugs, and anticholesteremic agents, the impact of these prescribed drugs on the blood glucose, serum insulin, and lipid profile could not be determined. Additionally, we did not control for diet; therefore, the effect of intake of fats and carbohydrates on the measured outcome variables could not be evaluated.

Conclusion

The results of our study indicate that a 6-month walking and stair-climbing exercise program is effective in improving the body composition and HbA1c levels of elderly subjects, with no specific additional benefit provided by including walking with BFR.

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Conflict of interest

No conflicts of interest, financial or otherwise, are declared by the authors.

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