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ORIGINAL ARTICLE

Favorable effects of non-instrumental resistance training on fat distribution and metabolic profiles in healthy elderly people

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Abstract This study examined the effect of a 12-week non-instrumental resistance training program using body weight as a load (RT-BW) on body composition, fat distribution and metabolic profiles in elderly males and females. Healthy, non-diabetic, elderly volunteers (22 males and 30 females) aged 65–82 years were non-randomly divided into RT-BW (12 males and 20 females) and control (10 males and 10 females) groups. The RT-BW subjects were trained three times per week for 12 weeks according to a specified protocol involving a combination of upper and lower body weight and rubber tubing exercises. We evaluated body composition and fat distribution using anthropometry, dual energy X-ray absorptiometry and ultrasonography, and measured serum lipid levels and HbA_{1c} at baseline and after 12 weeks of training. Changes over 12 weeks were significantly greater in the RT-BW group compared with the control group, with a decrease in waist circumference, pre-peritoneal (visceral) fat thickness and thigh fat thickness, and an increase in thigh muscle thickness. On the other hand, the changes in body weight, fat mass and fat free mass were no different between the groups. Further, there were significantly greater changes of metabolic profiles in the RT-BW group with an increase in HDL cholesterol and a decrease in triglyceride and HbA_{1c}. There was a significant between-group difference in diastolic blood pressure. Relatively short-term, non-instrumental resistance training using body weight as a load was effective in improving fat distribution and metabolic profiles in healthy elderly people without weight loss.

Keywords Resistance training · Visceral fat · Triglyceride · HDL cholesterol · HbA_{1c}

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Introduction

It is well established that diet and physical activity are the most important non-pharmacological measures to prevent diabetes mellitus, cardiovascular diseases and age-related musculoskeletal disorders, as well as to improve the quality of life in the elderly. Aerobic exercises have been widely recommended for the prevention of obesity, diabetes mellitus, hypertension, atherosclerotic cardiovascular disease and other chronic disabling conditions in elderly people (Williams et al. 2002; Thompson et al. 2003). In recent years, increasing attention has been paid to resistance training as a useful adjunctive tool of exercise (Pollock et al. 2000; Hunter et al. 2004). Resistance training programs in previous studies, however, require expensive exercise machines and supervised instruction. For some elderly people, access to exercise facilities is limited and compliance may be poor. In contrast, non-instrumental resistance training using body weight (RT-BW) and rubber tubes does not require special equipment or continuous supervision, and can be performed conveniently at anytime, any place and in any weather. Although these merits would enhance the compliance of RT-BW, there is a lack of data indicating beneficial effects from RT-BW on body composition, fat distribution and metabolic risk factors in the elderly. The purpose of this study is to assess the effect of a 12-week program of RT-BW on body composition, fat distribution and metabolic profiles in apparently healthy, elderly community residents.

Methods

Subjects

Twenty-three males and 32 females, aged 65 to 82 years, without experience in resistance training participated voluntarily in a community health promotion program. Study participants were recruited separately from different senior citizen clubs of two adjacent communities in the suburban areas of the same city (Handa, Aichi prefecture, Japan) which are considered socioeconomically similar. One of these clubs was non-randomly assigned to RT-BW group, and the other to control group. All these persons were retired and non-institutionalized. The control group did not receive any intervention but had a repeat measurement 12 weeks later. All subjects underwent anthropometric measurements, physical examination, medical history, living habits questionnaire, resting and exercise electrocardiograms, and blood tests and urinalysis. Those subjects with cardiovascular disease (determined by history or ECG findings), diabetes mellitus (by history or fasting plasma glucose > 125 mg/dl), uncontrolled hypertension (≥160/100 mmHg with or without medication), or taking antihyperlipidemic medication were excluded from the study. One male and two females were excluded from the study due to cardiovascular disease and diabetes mellitus. After being informed of the purpose of this study, all subjects gave their written informed consent. The study protocol was approved by the ethical committee of the National Hospital for Geriatric Medicine, Aichi, Japan.

Anthropometry and body composition

Anthropometric measurements were made with the subjects in their underwear, without socks and shoes, and in a standing position. Height was measured to the nearest 0.1 cm with an electric stadiometer. Body weight was measured to the nearest 0.1 kg with an electric scale. Body mass index (BMI) was expressed as weight in kg/(height in m)^2. Waist circumference was measured to the nearest 0.1 cm at the umbilicus level and the right thigh circumference was measured to the nearest 0.1 cm at the midpoint between the greater trochanter and the top of the patella. Body composition (fat mass and fat free mass) was assessed using dual energy X-ray absorptiometry (DXA, Hologic QDR-4500A, MA, USA). Anthropometric measurements were carried out by a single experienced person (TK). Coefficients of variation of all measurements were less than 2.0%.

Fat distribution

Fat distribution was assessed by B-mode ultrasonography (SSD-500, ALOKA, Aichi, Japan) with a linear-array probe (5 MHz) using the method described by Suzuki et al. (1993). Measurements were performed in the morning after overnight fast at baseline and repeated 5–7 days after the last exercise session in order to avoid any acute effects of RT-BW. Subjects were in the supine position with the probe held perpendicular to the skin on the upper median abdomen. Scanning was performed below the xiphoid process, and the surface of the liver was kept almost parallel to the skin while subjects held their breath. The minimum thickness of subcutaneous fat and the maximum thickness of pre-peritoneal fat below the xiphoid process were measured, assuming that the latter was equivalent to visceral fat area. Suzuki et al. (1993) reported a high correlation between visceral fat area assessed by CT and pre-peritoneal fat thickness assessed by ultrasonography ($r = 0.70$, $P < 0.001$). Subcutaneous fat thickness and muscle thickness at the right front thigh were also measured. Fat distribution measurements were carried out by a single experienced person (TK). Coefficients of variation of all measurements were less than 2.8%.

Blood chemistry and blood pressure

All blood chemistry determinations were performed in the morning after overnight fast at baseline and again

5–7 days after the last exercise session in order to avoid any acute effects of RT-BW. Standard enzymatic measurements of total cholesterol (TC), HDL cholesterol (HDL-C) and triglycerides (TG) were performed using HITACHI 7170 autoanalyzer (HITACHI, Tokyo, Japan), which were standardized according to the Centers for Disease Control (Fried et al. 1991). LDL cholesterol (LDL-C) concentrations were calculated using the Friedewald equation (Friedewald et al. 1972). Fasting plasma glucose and glycosylated haemoglobin (HbA_{1c}) were also measured directly by enzymatic assay procedures using Hitachi 7170. Systolic and diastolic blood pressures were measured using a standard sphygmomanometer in the sitting position after a 5-min rest in a quiet room. Average of two measurements was used for the analyses.

Resistance training protocol

The RT-BW program consisted of seven different exercises (squat, lunge, back kick, bent knee push up, sit up, row pulley, and shoulder press), which were designed to stimulate major muscles of the whole body. These exercises were initiated by two sets of 10 repetitions, and subsequently the number of repetitions was increased progressively by two repetitions every 4 weeks. All exercises were performed with the participant's body weight serving as a load. A rubber tube was used as an additional load only for row pulley and shoulder press since these exercises cannot stimulate target muscles using body weight alone. Squat was performed in the way that subjects stand with feet hip-width apart, and then bend their knees like sitting in a chair until the thighs become parallel to the floor. Lunge was performed in the way that subjects stand with feet hip-width apart, and then step forward with one leg and lower body down until back knee almost touches the floor. Back kick was performed in the way that subjects get on hands and knees, and lift one arm and opposite leg simultaneously. Bent knee push up was performed in the way that subjects take kneeling position, and then bend their elbows and lower the body until body almost touches the floor. Sit up was performed in the way that subjects lie supine on the floor with knees bent at 90° and hands are placed behind the neck. They pull the torso upward from a lying position toward as possible as they can and return until the back of the shoulders almost touches the floor. Row pulley was performed in the way that subjects sit upright with leg straight out in front of them. They place the tube around the bottom of feet and grasp the ends of rubber tube, and then pull the tube towards waist. Shoulder press was performed in the way that subjects stand grasping the ends of rubber tube at shoulder level and then lift the tube upward overhead.

The training sessions were performed three times per week (once at clinic and twice at home). At each clinic session, licensed supervisors instructed the participants to strictly follow the correct technique for each exercise movement so that target muscles could be sufficiently stimulated. Participants were instructed to perform each eccentric and concentric phase of movement slowly (spending 3 s for each movement, followed by 1 s holding) covering the full range of motion. It took approximately 40–50 min including a 10 min rest to complete all exercises. At home, participants performed these exercises in the same way as instructed at the clinic. For some females who experienced difficulty in bent knee push up and sit up, the load was reduced by narrowing moving ranges instead of changing the number of repetitions. Each participant submitted a home-based training log at the time of clinic sessions to ensure implementation of all exercises as instructed.

Diet intake and physical activity

The level of physical activity was evaluated for each participant by the average number of walking steps per day counted for 7 days using a pedometer (Select2, Suzuken, Aichi, Japan; Bassett et al. 2000). Dietary intake, smoking habits and alcohol consumption were assessed using simple frequency questionnaires at baseline and after 12 weeks. Based on self-reported usual frequency and portion size of food intake, total energy intake was estimated by dietitians using the Standard Tables of Food Composition in Japan, 4th revised edition. Furthermore, the two groups were instructed not to change their usual exercise and eating patterns during the study period.

Statistical analyses

All data are expressed as means ± standard deviations. The statistical significance of the difference in each parameter between the RT-BW and control groups at baseline was determined using unpaired t test. Differences at 12 weeks of intervention were calculated by subtracting the within-group changes from baseline for the control group from the within-group changes for the RT-BW group. For each variable, the significance of between-group differences in changes over 12 weeks was examined using two-way analysis of variance. Dependent variable was difference in measured parameters before and after the intervention. Independent variables included the RT-BW group, the control

Table 1 Baseline characteristics of subjects

	RT-BW	Control
Number of subjects	32	20
Sex (M/F)	12/20	10/10
Mean age (yr)	69.4 ± 2.8	70.2 ± 3.9
Total energy intake (kcal)	1803.6 ± 396.7	1821.8 ± 245.9
Walking steps (steps/day)	8764 ± 2527	8233 ± 2365
Current smoker (%)	15.6	15.0
Systolic blood pressure (mmHg)	131.5 ± 20.9	124.4 ± 19.3
Diastolic blood pressure (mmHg)	72.4 ± 10.8	67.9 ± 11.4
Body weight (kg)	54.6 ± 8.1	55.2 ± 8.3
BMI (kg/m^2)	22.9 ± 2.2	22.7 ± 3.2
Fat mass (kg)	16.7 ± 3.5	15.1 ± 5.5
Fat free mass (kg)	38.0 ± 6.9	40.2 ± 6.2
Waist circumference (cm)	79.3 ± 9.4	80.2 ± 9.0
Subcutaneous fat thickness (mm)	15.6 ± 4.5	13.4 ± 5.4
Pre-peritoneal fat thickness (mm)	10.4 ± 2.8	10.6 ± 3.1
Thigh circumference (cm)	49.1 ± 2.7	47.7 ± 4.3
Thigh muscle thickness (mm)	31.5 ± 5.0	32.6 ± 6.4
Thigh fat thickness (mm)	10.1 ± 1.9	9.7 ± 2.3
Total-cholesterol (mg/dl) *	227.4 ± 30.7	210.5 ± 25.5
Triglyceride (mg/dl)	137.7 ± 68.6	115.5 ± 52.0
HDL-cholesterol (mg/dl)	60.1 ± 15.0	58.0 ± 16.3
LDL-cholesterol (mg/dl)	139.7 ± 27.9	130.0 ± 22.5
Fasting plasma glucose (mg/dl)	96.4 ± 6.1	95.4 ± 4.8
HbA_{1c} (%)*	5.4 ± 0.6	5.0 ± 0.4

Data presented by mean ± SD

RT-BW Resistance training using body weight, *BMI* body mass index, *HDL* high density lipoprotein, *LDL* low density lipoprotein, HbA_{1c} haemoblobin A_{1c}

*At baseline, there were no significant differences in all parameters between RT-BW and control groups except Total-cholesterol and HbA_{1c} ($P < 0.05$)

group and sex. In order to examine possible interaction between sex and intervention group, we added interaction term (sex × group). Since no significant interaction between sex and groups was noted for all of the measured variables, the final data were presented pooling males and females (Tables 1, 2). Furthermore, the paired *t* test was used to examine the within-group changes in each parameter before and after 12 weeks of intervention for the RT-BW group and the control group. A *P* value < 0.05 was considered statistically significant. The analyses were performed using the SPSS statistical software package (SPSS Inc, IL, USA).

Results

The average rate of attendance at the supervised training session was 91%. However, all participants in the RT-BW group including those who failed to attend the clinic sessions implemented the training program twice a week at home without supervision. This has been confirmed by the training logs at home. No subject dropped out of the study. Table 1 shows characteristics of the subjects at baseline. There was no significant difference at baseline in any of the variables between the RT-BW and control groups except for higher TC and HbA_{1c} in RT-BW. Table 2 shows absolute changes from baseline for the RT-BW and control groups, and differences between groups.

Changes over 12 weeks were significantly greater in the RT-BW group compared with the control group in the following measurements: a decrease in waist circumference ($P < 0.001$), pre-peritoneal (visceral) fat thickness ($P < 0.01$) and thigh fat thickness ($P < 0.01$), and an increase in thigh muscle thickness ($P < 0.01$). On the other hand, there was no significant difference in the temporal change between the two groups for body weight, BMI, total body fat mass, fat free mass, abdominal subcutaneous fat thickness and thigh circumference. As to the metabolic profiles, there was a significantly greater temporal change in the RT-BW group compared with the control group, with an increase in HDL-C ($P < 0.01$) and a decrease in TG ($P < 0.001$) and HbA_{1c} ($P < 0.01$). There was no significant difference in the temporal change between the two groups for TC, LDL-C and fasting plasma glucose. A significant between-group difference in blood pressure changes over 12 weeks was noted only in diastolic levels, which decreased in the RT-BW group and increased in the control group. A similar trend was noted for systolic blood pressure but the difference was not significant. Further, there was no significant difference in the temporal change between the two groups for total energy intake and walking steps.

Discussion

Until recently, research on the effect of physical activity in elderly people has focused on aerobic exercise and resistance training using exercise machines or free weights (Williams et al. 2002; Thompson et al. 2003; Pollock et al. 2000; Hunter et al. 2004; Ibanez et al. 2005; Fahlman et al. 2002; Dunstan et al. 2002). To our knowledge, the present study is the first report which has demonstrated that a non-instrumental resistance training using body weight as a load appears to be effective in lowering blood pressure, decreasing visceral fat and improving metabolic profiles (TG, HDL-C and HbA_{1c}), without changing body weight, BMI and total body composition, in healthy non-obese elderly people.

In general, the intensity of non-instrumental resistance training is considered to be lower than that of resistance training using exercise machines or free weights. Since it is impossible to assess the intensity of non-instrumental resistance training, we cannot

Table 2 Changes in the measured variables over 12-week intervention for the RT-BW and control groups, and differences in those changes between groups

	Changes from baseline levels		Between- group differences in changes from baseline levels (95% confidence interval)
	RT-BW (n = 32)	Control (n = 20)	
Total energy intake (kcal)	116.6 ± 339.8	112.0 ± 310.7	4.6 (−183.8 to 193.0)
Walking steps (steps/day)	−418 ± 1558	−740 ± 1629	322 (−732 to 1376)
Systolic blood pressure (mmHg)	−5.1 ± 17.2	3.5 ± 15.0	−8.6 (−18.0 to 0.8)
Diastolic blood pressure (mmHg)	−5.1 ± 14.3*	2.9 ± 9.7	−8.0 (−15.3 to −0.6)†
Body weight (kg)	−0.4 ± 1.5	−0.2 ± 1.2	0.0 (−0.5 to 0.1)
BMI (kg/m^2)	−0.3 ± 0.6*	−0.1 ± 0.5	−0.1(−0.5 to 0.2)
Fat mass (kg)	−0.7 ± 0.9***	−0.5 ± 0.7*	−0.3(−0.8 to 0.2)
Fat free mass (kg)	0.5 ± 0.8**	0.2 ± 0.9	0.3(−0.2 to 0.8)
Waist circumference (cm)	−1.3 ± 1.3***	−0.1 ± 1.0	−1.1 (−1.8 to −0.4)†††
Subcutaneous fat thickness (mm)	−0.7 ± 1.5*	0.0 ± 1.2	−0.7 (−1.5 to 0.1)
Pre-peritoneal fat thickness (mm)	−1.2 ± 1.3***	−0.2 ± 1.8	−1.1 (−1.9 to −0.2)††
Thigh circumference (cm)	−0.3 ± 1.2	−0.4 ± 1.4	0.1 (−0.7 to 0.8)
Thigh muscle thickness (mm)	2.0 ± 2.7***	−0.4 ± 2.2	2.3 (0.9 to 3.8)††
Thigh fat thickness (mm)	−0.9 ± 1.0***	−0.3 ± 0.7	−0.6 (−1.2 to −0.1)††
Total-cholesterol (mg/dl)	−1.4 ± 23.2	2.5 ± 19.0	−3.8 (−16.2 to 8.6)
Triglyceride (mg/dl)	−31.8 ± 45.2***	30.2 ± 45.7**	−62.1 (−88.5 to −35.7)†††
HDL-cholesterol (mg/dl)	4.1 ± 6.6**	−1.9 ± 7.3	6.0(2.1 to 9.9)††
LDL-cholesterol (mg/dl)	0.9 ± 19.4	−2.7 ± 19.0	3.6 (−7.6 to 14.8)
Fasting plasma glucose (mg/dl)	−1.7 ± 8.1	2.4 ± 7.2	−4.0(−8.5 to 0.4)
HbA_{1c} (%)	−0.5 ± 0.5***	−0.1 ± 0.4	−0.4(−0.6 to−0.1)††

Data presented by mean ± SD; a positive sign indicates an increase and a negative sign indicates a decrease

RT-BW Resistance training using body weight, *BMI* body mass index, *HDL* high density lipoprotein, *LDL* low density lipoprotein, HbA_{1c} Haemoblobin A_{1c}

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$ within-group change from baseline

†††$P < 0.001$, ††$P < 0.01$, †$P < 0.05$ between-group difference in change from baseline

directly compare our study results with those using exercise machines or free weights. However, the speed of resistance training performance might exert a significant influence independently of the intensity of exercise. Recently, Tanimoto et al. (2006) investigated the effect of resistance exercise (knee extension) on the thigh muscle size and strength in relation to the intensity and speed of exercise. Twenty-four healthy young men were assigned randomly into three groups: low-intensity (50% of one repetition maximum) with slow movement and tonic pause (3 s for each eccentric and concentric action, 1 s pause, and no relaxing phase; LST); high-intensity (80% of one repetition maximum) with normal speed (1 s for each eccentric and concentric action, 1 s for relaxing; HN); and low-intensity with normal speed (same intensity as for LST and same speed as for HN; LN). Each exercise session consisting of three sets was performed three times a week for 12 weeks. They found that LST and HN groups showed a significant increase in cross-sectional area determined by MRI and isometric strength of knee extensors, whereas no significant change was seen in LN group. These results suggest that the slow speed with a tonic pause in a resistance exercise is as important as the intensity to increase muscle size and strength.

In our study, participants were instructed to perform each eccentric and concentric phase of movement slowly (spending 3 s for each movement, followed by 1 s holding) covering the full range of motion. If the findings in Tanimoto's study are applicable to other muscles, the effects of seven exercises in our study may well be as strong as those in high-intensity resistance training with normal speed. A significant increase in thigh muscle thickness in our study may support this interpretation. However, there was no significant difference in the temporal change between the two groups for the total fat free mass. This might be explained by the following. First, since total fat free mass includes water, bones and soft tissues other than muscles, the fat free mass change does not directly reflect change in muscle mass. Second, it may require further time for the between-group difference in the temporal change of total fat free mass to reach the statistically significant level.

The beneficial effects of RT-BW on fat distribution (visceral fat and thigh fat thickness) are consistent with those for resistance training using exercise machines reported previously. For example, Treuth et al. (1995) investigated effects of the resistance training using exercise machines with moderate intensity for

16 weeks in healthy older women. In their study, CT was used to measure abdominal (subcutaneous and intra-abdominal) adipose tissue, thigh fat and thigh muscle area. They found that a significant reduction in intra-abdominal adipose tissue, thigh fat and an increase in thigh muscle without change in body weight, fat mass, fat free mass and abdominal subcutaneous adipose tissue.

There was a significant increase in HDL-C and a decrease in TG and HbA_{1c} in the RT-BW group compared with the control group. These findings are in accordance with the previous studies which have demonstrated that aerobic exercise and resistance training using exercise machines improve glycemic control and lipid profiles (Williams et al. 2002; Thompson et al. 2003; Pollock et al. 2000; Hunter et al. 2004; Ibanez et al. 2005; Fahlman et al. 2002; Dunstan et al. 2002; Nicklas et al. 2004; Kobayashi et al. 2001). For example, Fahlman et al. reported a significant change in HDL-C and TG without change in body weight after 10-week resistance training in healthy elderly women. Dunstan et al. reported a significant reduction in HbA_{1c} after 3-month high-intensity progressive resistance training, in combination with moderate weight loss, in older patients with type 2 diabetes. In contrast, there was no significant change in the group without resistance training. Despite significant improvements in HbA_1c (a measure of average glucose levels during the past 4–8 weeks), fasting plasma glucose was not significantly different. This may be partly explained by exclusion of diabetics with fasting plasma glucose greater than 125 mg/dl. Diabetic levels of fasting plasma glucose might have shown a greater response to the resistance training.

Accumulation of abdominal fat is associated with reduced metabolic clearance of insulin due to diminished hepatic insulin extraction. It has been suggested that a high plasma concentration of free fatty acids originating from the abdominal visceral fat through the portal circulation inhibits the binding and uptake of insulin in hepatocytes, which can lead to insulin resistance. Thus, reduction in visceral fat by resistance training may improve lipid profiles and glucose metabolism through attenuating insulin resistance. The result of the present study appears to support these findings.

Our results of reducing diastolic blood pressure in the RT-BW group were in accord with previously reported meta-analyses which showed approximately 3 mmHg decrease as a result of high-intensity resistance training in hypertensive patients (Conelissen et al. 2005; Kelly et al. 2000). This might be partly explained by the reduction of visceral fat and improved metabolic profiles which lead to lowering blood pressure levels as suggested in several reports. This beneficial effect of resistance training appears to be primarily attributed to the reduction of visceral fat resulting in the improvement of insulin resistance, sympathetic nerve activity, Renin-Angiotensin system response, levels of adipocytekines and other proinflammatory/prothrombotic factors, which lead to lowering blood pressure levels as suggested in several reports (Blair et al. 1984; Iso et al. 1991; Sironi et al. 2004; Hayashi et al. 2004; Poirier et al. 2005). Since the baseline blood pressure levels (systolic and diastolic) in the RT-BW group were higher than those in the control group, although not significant, 12-week changes between the two groups might have been affected by baseline levels. However, when a baseline blood pressure was included as a covariate in the statistical analysis, there remained a significantly greater change in diastolic blood pressure in the RT-BW group compared with the control group.

However, there are several limitations in the present study, including a small sample size, non-randomization, a relatively short-term intervention and no follow-up to examine the persisting effects. Furthermore, the study subjects are considered to be highly motivated elderly persons, so generalizability of the results needs to be verified using larger population-based samples.

In conclusion, a relatively short-term, non-instrumental resistance training using body weight as a load was effective in lowering diastolic blood pressure, decreasing visceral fat, increasing HDL-C and decreasing TG and HbA_{1c} in healthy non-obese elderly people, without change in body weight and total fat mass and fat free mass. Since all these parameters are essential components of the metabolic syndrome (Grundy et al. 2004; Eckel et al. 2005), the present study findings appear to indicate the usefulness of resistance training using body weight as a preventive measure of diabetes mellitus and cardio vascular disease.

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Author contributions: study concept and design, acquisition of subjects and data, analysis and interpretation of data, and preparation of manuscript (Dr. Tsuzuku, Dr. Kajioka and Dr. Endo); analysis and

interpretation of data, and preparation of manuscript (Dr. Abbott); and preparation of manuscript (Dr. Curb and Dr. Yano).

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