The influence of weight reduction programs consisting of caloric restriction and/or exercise on the vital age of men with obesity

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Bokun Kim[1ABDE], Seungyeol Kim[2ACD]

[1] Meadowbank College of TAFE, Sydney, Australia
[2] College of Arts and Sports, Dong-A University, Busan, South Korea

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Abstract

Background and Study Aim: Obesity is deeply related to a broad range of internal conditions, including heart disease, hypertension, and diabetes, as well as several musculoskeletal conditions, such as pain, stiffness, loss of joint mobility, osteoarthritis, tendinitis, and back pain. The purpose of this study was the influences of weight reduction programs consisting of caloric restriction and/or exercise on the vital age of men with obesity.

Material and Methods: For 12 weeks, 32 subjects (G_E) attended exercise class 3 days/week and 79 subjects (G_{CE}) concurrently attended exercise class 3 days/week and a caloric restriction class 1 day/week. Changes of weight and the following nine necessary variables were assessed to compute vital age: subscapular skinfold thickness, systolic blood pressure, total cholesterol, triglycerides, oxygen uptake and heart rate corresponding to lactate threshold (VO_{2LT} and HR_{LT}, respectively), stepping side-to-side, one leg balance with eyes closed and forced expiratory volume in one second.

Results: Changes of weight for the subjects in the G_E and G_{CE} were −2.4% and −13.8%, respectively ($p<0.01$ for both). G_E showed amelioration of subscapular skinfold thickness, total cholesterol and side stepping, whereas every component of vital age except for HR_{LT} was ameliorated in G_{CE}. The stronger influences on four components of vital age including systolic blood pressure, total cholesterol, triglyceride and forced expiratory volume in one second were detected in the G_{CE}. As a result, improvement of vital age was detected within G_C and G_{CE}, by 8.4 % and 18.9 %, respectively ($p<0.01$ for both). When intergroup comparison was made, the improvement in G_{CE} was greater than that in the G_C ($p<0.01$).

Conclusions: Vital age was predominantly affected by caloric restriction, and combining exercise with caloric restriction yielded additional improvement in vital age.

Keywords: biological vitality • risk factors • vital age

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Author's address: Seungyeol Kim, College of Arts and Sports, Dong-A University, 37 Nakdong-Daero 55 0beon-gil Saha-Gu, Busan 604-714, South Korea; e-mail: srkimjp@hanmail.net

BMI – body mass index.

$FEV_{1.0}$ – forced expiratory volume for 1 sec.

HDLC – High-density lipoprotein cholesterol.

HR_{LT} – heart rate at the lactate threshold.

LDLC – low-density lipoprotein cholesterol.

SBP – systolic blood pressure.

TC – total cholesterol.

TG – triglyceride.

Vital age – a level of biological vitality.

VO_{2LT} – oxygen uptake at the lactate threshold.

Obesity – ***noun*** the condition of being seriously overweight [30].

Exercise – ***noun*** **1.** physical or mental activity, especially the active use of the muscles as a way of keeping fit, correcting a deformity or strengthening a part **2.** a particular movement or action designed to use and strengthen the muscles ■ ***verb*** **1.** to undertake physical exercise in order to keep fit and healthy **2.** to subject the body, or part of it, to repetitive physical exertion or energetic movement in order to strengthen it or improve its condition [30].

Fitness level – ***noun*** how to fit a person is, from absolute beginner to trained athlete [30].

Physical activity – ***noun*** exercise and general movement that a person carries out as part of their day [30].

Brisk – ***adjective*** did quickly and energetically [30].

Hypertension – ***noun*** arterial blood pressure that is higher than the usual range for gender and age. Also called **high blood pressure**, **hyperpiesia**. Compare **hypotension [30].**

Hypotension – ***noun*** a condition in which the pressure of the blood is unusually low. Also called **low blood pressure** [30].

Stiff – ***adjective*** not able to be bent or moved easily [30].

INTRODUCTION

As dietary habits and lifestyles in Japan are becoming closer to those of Western countries, the prevalence of obesity among the adult population is approximately 30% and has increased nearly 1.5-fold over the last 30 years among men [1]. Obesity is deeply related to a broad range of internal conditions, including heart disease, hypertension, and diabetes, as well as several musculoskeletal conditions, such as pain, stiffness, loss of joint mobility, osteoarthritis, tendinitis, and back pain [2-7]. Due to these conditions, socioeconomic problems related to obesity are becoming serious, and establishing countermeasures is urgent [2].

As a countermeasure, a weight reduction program consisting of exercise and/or caloric restriction has been strongly recommended [4, 8-10]. Since energy expenditure alone is generally not enough for adult men to lose weight, exercise is usually combined with caloric restriction [11]. According to existing studies reporting a weight reduction program, caloric restriction contributes more to weight reduction than exercise [12]. However, it is not adequate to evaluate the efficiency of a weight reduction program based on the degree of weight reduction. The changes in blood pressure, plasma lipid profiles, physical fitness, etc., should also be evaluated.

“Biological vitality” is one of the indexes used to evaluate factors associated with health status and physical fitness. Tanaka et al. [13] defined “vital age” as the “level of biological vitality”, and it comprises behavioural, physical fitness factors such as cardiorespiratory endurance and coronary heart disease risk factors. It has been employed to evaluate the influence of exercise on older adults and adults with medical conditions [14]. Also, it was applied to assess the efficiency of a weight reduction program for women with obesity [15]. The existing studies have reported that a weight loss program consisting of exercise and caloric restriction noticeably ameliorates vital age [15]. However, the influences of exercise alone have not been adequately investigated, and it remains uncertain whether a younger vital age is induced by exercise or by combining exercise and caloric restriction. Therefore, in this study, we conducted weight reduction programs consisting of caloric restriction and/or exercise

The purpose of this study was the influences of weight reduction programs consisting of caloric restriction and/or exercise on the vital age of men with obesity.

MATERIAL AND METHODS

Subjects

A total of 262 Japanese men recruited from Ibaraki prefecture through advertisements of a 12-week lifestyle modification program which was consisted of exercise and/or caloric restriction. The program consisting of exercise and caloric restriction was conducted in 2011-2013, and exercise alone was performed in 2014 and 2015. The following inclusion criteria were applied: 1) males between 30 and 64 years of age; 2) body mass index (BMI)25 kg/m2, according to Japanese obesity guidelines; 3) not restricted from exercising by a doctor; and 4) not to engage in exercise frequently. As shown figure 1, we excluded subjects who were not eligible for the present study (n = 22), did not participate in assessment (n = 25), had incomplete data (n = 57), dropped out (n = 32) and had low attendance rate (< 30%) (n=15). Finally, of the initial 262 applicants, 111 subjects were included in the analysis. Each subject provided written informed consent, which was approved by the institutional review board. This study was conducted in accordance with the guidelines proposed in the Declaration of Helsinki, and its protocol was reviewed and approved by the Ethics Committee of the University of Tsukuba, Japan.

Study design

A 12-week lifestyle modification program consisting of caloric restriction and/or exercise was performed to positively influence the subjects’ lifestyles. Every assessment was conducted before the program and repeated within 2 weeks after completing the program.

Exercise program

Every subject took part in a 90-min combined exercise program 3 days/week for 12 weeks. Each session began with 10-20 min of warm-up activities such as stretching. This was followed by the main exercise, 40-60 min of brisk walking and jogging outdoors. On rainy days, indoor exercise consisting of stationary cycling and ladder climbing was the main exercise. Each session concluded with 10-20 min of body-weight resistance exercise and cool-down exercises. Every exercise was executed under the supervision of several trained physical trainers at the University of Tsukuba. Subjects were encouraged to exercise at their maximum heart rate level or near their maximum heart rate level. Heart rates were monitored by short-range telemetry (Polar RS400, Kempele, Finland). Subjects were allowed to participate in their preferred type of physical activity on days without the exercise class.

Caloric restriction program

This program was based on the Four-Food-Group Point Method, and each group-based instructional class consisted of a dietary lecture and a small interactive group session lasting 90 min. The classes were held twelve times during the 12 weeks. The Four-Food-Group Point Method divides a diet into the following four food groups based on nutritional content: group 1 (dairy products and eggs), group 2 (beans, fish, and meat), group 3 (fruits and vegetables), and group 4 (sugar and grains). For the nutrient balance calculations and measurements of energy intake, all foods were portioned into 80 kcal servings, and each portion was regarded as 1 point. For each meal, the subjects were instructed to select 1, 2, 1, and 3 points of diverse foods from food groups 1, 2, 3, and 4, respectively, to consume a well-balanced daily diet. Accordingly, the subjects ingested ~21 points of food per day, which corresponded to 1,680 kcal/d. The subjects maintained a daily food diary, in which they recorded all the food that they consumed. During each class, the dieticians reviewed the subjects' diaries and provided them with individualized feedback regarding their energy intake and nutritional balance. Total energy intake (kcal/d) and the intake amounts (g/d) of each nutrient (carbohydrate, protein, and fat) were assessed before and at the end of the dietary restriction program using a 3-day diet record conducted by a skilled dietitian.

Assessments

Daily energy intake

Total energy intake (Kcal/d) and the intake amounts (g/d) of each nutrient (carbohydrate, protein and fat) were assessed before and at the end of the program using a 3-day diet record performed by a skilled dietitian.

Stiffness – *noun* the fact of being stiff [30].

Osteoarthritis – *noun* a degenerative disease of middle-aged and older people characterised by inflamed joints which become stiff and painful [30].

Tendinitis – *noun* inflammation of a tendon, especially after playing sport, and often associated with tenosynovitis [30].

Coronary heart disease – *noun* any disease that affects the coronary arteries and may lead to strain on the heart or a heart attack. Abbreviation **CHD** [30].

Cardiorespiratory endurance – the ability of heart, lungs, and circulatory system to supply oxygen to working muscles efficiently [31].

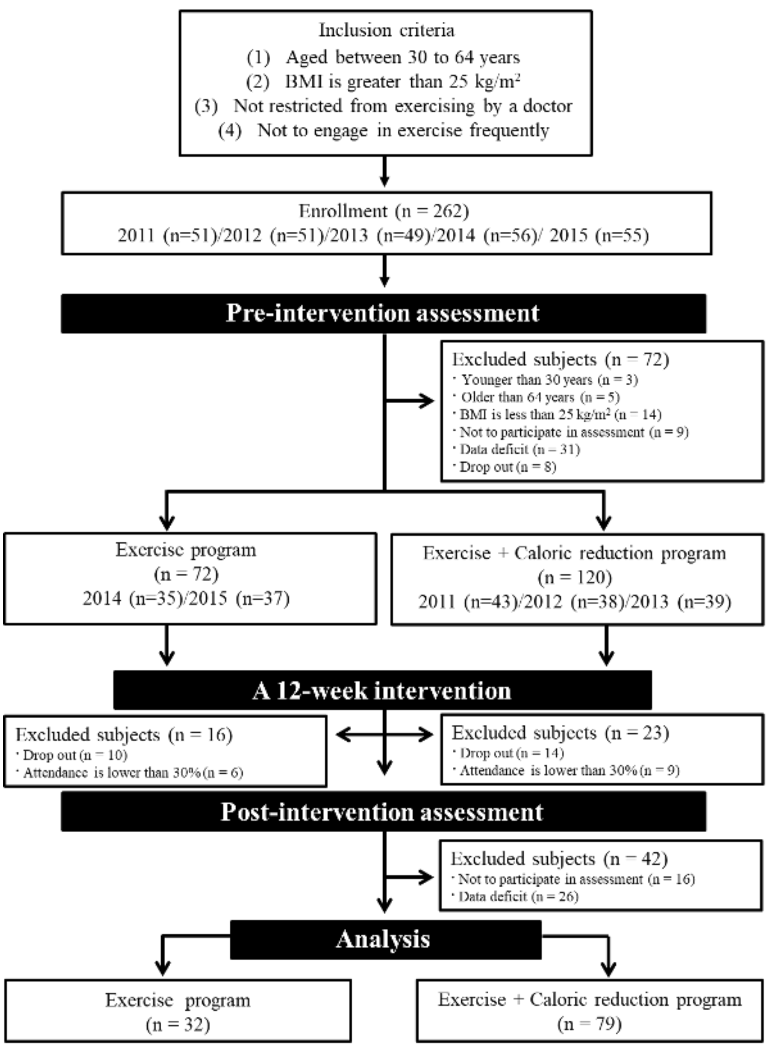

Figure 1. Flow chart of the study subjects.

Step frequency

Step frequency was assessed using a single-axis pedometer (Lifecorder; Suzuken Co. Ltd., Nagoya, Japan). The pedometer was attached to the subject's clothing during all daily activities except while sleeping and bathing, beginning two weeks prior to the program period and throughout the entire program. Detailed descriptions of the accelerometer have been published previously by Kumahara et al. [16].

Anthropometry and body composition

Height was assessed to the nearest 0.1 cm using a wall-mounted stadiometer (YG-200; Yagami, Nagoya, Japan), and body weight were assessed to the nearest 0.1 kg using a digital scale with the subject in light clothing and without shoes (TBF-551; Tanita, Tokyo, Japan). BMI was computed as weight (kg) divided by height (m) squared.

Body composition was assessed using whole-body dual energy X-ray absorptiometry (DEXA; QDR 4500, Hologic Inc., Bedford, MA, USA). Hologic software was employed to estimate fat and lean masses (kg), and percentage of fat mass (%).

Components of vital age

A graded exercise test using a cycle ergometer (818E, Monark, Stockholm, Sweden) was carried out to assess oxygen uptake and heart rate corresponding to lactate threshold (VO_{2LT} and HR_{LT}, respectively) by a multi-stage incremental load protocol that involved increasing the friction load by 0.25 kp per min. The pedalling speed was constant at 60 rpm. To analyse expired gas components, a metabolic assessment unit (Oxycon Alpha System, Mijnhardt Breda, The Netherlands) was employed. For lactate

Table 1. Baseline and changes in energy intake and step frequency in both groups (part 1).

Stage and variable	G_E (n = 32)		G_{CE} (n = 79)		p for interaction
	Mean	SD	Mean	SD	
Total energy intake, [Kcal/d]					
Baseline	2171.2	477.7	2148.5	488.9	
After	2079.2	440.3	1482.7	280.7	
Change	−92.0	419.2	−665.7	424.5	<0.01
Carbohydrate intake, [g/d]					
Baseline	280.1	71.1	289.0	77.3	
After	272.7	68.2	200.2	40.8	
Change	−7.4	70.5	−88.8	77.5	<0.01
Protein intake, [g/d]					
Baseline	80.5	23.7	77.5	17.8	
After	73.4	13.9	71.2	14.6	
Change	−7.2	17.2*	−6.2	16.7	0.791
Fat intake, [g/d]					
Baseline	67.0	19.1	59.9	16.3	
After	61.0	16.6	41.6	11.1	
Change	−6.0	18.7	−18.3	16.6	<0.01
Step frequency, [step/d]					
Baseline	7390.4	2555.3	7964.1	3030.5	
After	10813.2	3198.3	11710.5	3357.8	
Change	3422.8	2467.4	3746.4	2399.2	0.522

threshold (LT), approximately 1 ml of blood was drawn from the antecubital vein of the arm each minute during the exercise test, and the lactate concentration was analysed by a lactate analyser (1500 L, YSI Life Sciences, Yellow Springs, OH). When blood collection was difficult, LT was detected by examining the relationship of VCO_2 to VO_2 (V-slope method). Also, other expired gas variables and the cardiorespiratory endurance prediction formula of Okura & Tanaka [17] were supplementally employed.

Blood samples were collected in the morning after fasting for 12 hours or more. The concentrations of TC and TG were analysed by the enzymatic colourimetric method, high-density lipoprotein cholesterol (HDLC) was analysed by the modified enzymatic method, and LDLC was analyzed by the formula of Friedewald et al. [18]: LDLC = TC – (HDLC + TG/5). Hct was analysed by the RBC cumulative pulse height detection.

Assessments of other variables were conducted as in previous studies [19, 20]. Every variable was assessed before and after the lifestyle modification program, and vital age was computed with the formula:

$$VA = 8.90VS + 0.33CA + 32.83$$

$$VS = -1.035 + 0.016X_1 + 0.011X_2 - 0.064X_3 - 0.012X_4 + 0.004X_5 + 0.004X_6 + 0.004X_7 + 0.034X_8 - 0.037X_9 - 0.005X_{10} - 0.036X_{11}$$

Legend: **VA** vital age (year); **VS** vital score; **CA** chronological age (year); $\mathbf{X_1}$ subscapular skinfold thickness (mm); $\mathbf{X_2}$ systolic blood pressure (mmHg); $\mathbf{X_3}$ total cholesterol (mg/dl); $\mathbf{X_4}$ triglycerides (mg/dl); $\mathbf{X_5}$ VO_{2LT} (ml/kg/min); $\mathbf{X_6}$ HR_{LT} (beat/min); $\mathbf{X_7}$ stepping side-to-side (n/20 s); $\mathbf{X_8}$ one leg balance with eyes closed (s); $\mathbf{X_9}$ forced expiratory volume in one second (l).

Table 2. Baseline and changes in anthropometric and body composition characteristics in both groups.

Stage and variable	G_E (n = 32)		G_{CE} (n = 79)		p for interaction
	Mean	SD	Mean	SD	
Chronological age, [year]	48.4	7.2	49.7	9.4	
Height [cm]	173.2	5.4	170.3	6.1	
Weight [kg]					
Baseline	85.8	13.3	85.3	10.5	
After	83.7	13.5	73.5	10.0	
Change	–2.1	3.1	–11.8	4.5	<0.01
BMI [kg/m²]					
Baseline	28.5	3.5	29.4	2.6	
After	27.8	3.5	25.3	2.6	
Change	–0.7	1.0	–4.0	1.5	<0.01
Lean mass [kg]					
Baseline	64.6	8.0	63.5	7.6	
After	64.0	7.9	58.4	6.9	
Change	–0.6	17.4	–5.1	2.5	<0.01
Fat mass [kg]					
Baseline	22.8	6.7	21.2	4.5	
After	21.3	6.6	14.7	4.4	
Change	–1.5	2.1	–6.5	2.4	<0.01
Percentage of fat mass [%]					
Baseline	25.3	4.3	24.5	3.5	
After	24.6	4.0	19.5	3.9	
Change	–0.7	1.9*	–5.0	2.1	<0.01

Statistical analysis

Values are expressed as the means and standard deviations (SD). The unpaired *t*-test was employed to assess the statistical significance of between-group differences at baseline. The comparison of variables before and after the program was conducted using the paired *t*-test. To compare the changes between groups, we applied a two-way, repeated-measures analysis of variance (ANOVA). $P < 0.05$ indicated statistical significance. Every statistical analysis was performed with SPSS software, version 21.0 (IBM Inc., Armonk, NY, USA).

RESULTS

At baseline, no noticeable differences were detected in any of the variables related to energy intake and step frequency. After the program, noticeable changes were not detected in total energy, carbohydrate and fat intake, but a noticeable decrease was detected in protein intake in the G_E (exercise group) ($p < 0.05$). All variables related to energy intake decreased noticeably in the G_{CE} (caloric restriction + exercise group) ($p < 0.01$ for all). Except for protein intake ($p = 0.791$), noticeable interactions were detected for all variables between the two groups ($p < 0.01$ for all). For step frequency, a noticeable difference was not detected between the two groups at baseline. After the program, noticeable increases were detected in both groups ($p < 0.01$ for both). However, noticeable interactions were not detected between the two groups ($p = 0.522$) (Table 1).

There were no noticeable differences between the two groups in any of the baseline measurements. Noticeable decreases were detected for the weight (−2.4%), BMI (−2.5%), fat mass (-6.6%) and percentage of fat mass (−2.9%) in the G_E group but not for lean mass (−1.0%). All of the variables, including weight (−13.8%), BMI (−13.7%), lean mass (−8%), fat mass (−30.7%), and percentage of fat mass (−20.6%), decreased noticeably in the G_{CE} group. ANOVA revealed noticeable interactions for all variables between two groups ($p < 0.01$ for all) (Table 2).

Noticeable differences were not detected in vital age between the two groups before the program. Remarkable improvement was discovered in the G_C and G_{CE} groups by 8.4% and 18.9%, respectively ($p < 0.01$ for both). When an intergroup comparison was made, the improvement in the G_{CE} group was noticeably higher than that of the G_C group ($p < 0.01$) (Figure 2).

Before the program, no noticeable differences were detected in any of the variables between the two groups. Of the nine components of vital age, three variables, including subscapular skinfold thickness (−23.2%), total cholesterol (−2.3%) and sidestepping (+8.6%), in the G_E group and eight

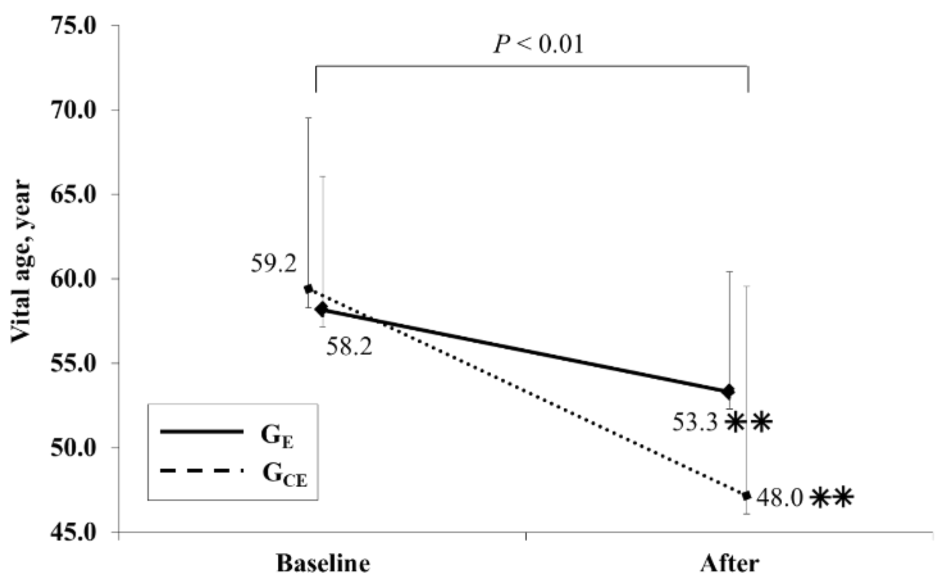

Figure 2. Changes in vital age in G_E and G_{CE} (significant change within a group using a paired t-test $^{*}p < 0.05$, $^{**}p < 0.01$).

variables, including subscapular skinfold thickness (−27.9%), SBP (−10.6%), VO_{2LT} (+16.2%), total cholesterol (−12.2%), triglycerides (−50.7%), sidestepping (+6.2%), balance (+53.7%) and $FEV_{1.0}$ (+2.7%), in the G_{CE} group were noticeably changed after the program. When an intergroup comparison was made, the magnitude of the changes in SBP ($p < 0.01$), total cholesterol ($p < 0.01$), triglycerides ($p < 0.01$) and $FEV_{1.0}$ ($p < 0.05$) was noticeably higher in the G_{CE} group than in the G_E group (Table 3).

DISCUSSION

Since vital age as defined by Tanaka et al. [13] includes oxygen uptake, heart rate and behavioural, physical fitness factors, as well as the results of physiological assessments' during rest hours, it can be adopted as a comprehensive index. The primary findings of this study were as follows: First, the combination of exercise and caloric restriction had a better influence on weight reduction compared to exercise alone. The combination of exercise and caloric restriction also induced a greater decrease in lean and fat mass than exercise alone. Second, exercise alone caused amelioration of the subscapular skinfold thickness, total cholesterol and side-stepping components of vital age, whereas every component of vital age except for HR_{LT} was improved by a combination of exercise and caloric restriction. A combination of exercise and caloric restriction had a strong influence on four components of vital age, including SBP, total cholesterol, triglycerides and $FEV_{1.0}$. Third, vital age in the G_E and G_{CE} groups changed by −4.9 and −11.2 years, respectively ($p < 0.01$ for both). The combination of caloric restriction and exercise had a better influence on vital age compared to exercise alone ($p < 0.01$). These results suggest that vital age was mainly enhanced by caloric restriction and that exercise strengthened the influence of caloric restriction on vital age.

After taking part in each program, the step frequency in both groups noticeably increased, but the changes in total energy intake showed different results. As we expected, the total energy intake was statistically unchanged in the G_E group and noticeably decreased in the G_{CE} group. As a result, the weight of the subjects in the G_E and G_{CE} groups decreased 2.4% ($p < 0.01$) and 13.8% ($p < 0.01$), respectively, and everybody composition-related variable, including lean mass (5.1% in the G_{CE} group), fat mass (1.5% in the G_E group and 6.5% in the G_{CE} group), and percentage of fat

Table 3. Baseline and changes in components of vital age in both groups.

Stage and variable	G_E (n = 32)		G_{CE} (n = 79)		p for interaction
	Mean	SD	Mean	SD	
Subscapular skinfold thickness (X_1) [mm]					
Baseline	37.1	7.6	33.2	9.4	
After	28.5	10.5	23.9	8.9	
Change	−8.6	8.3	−9.3	5.6	0.638
SBP (X_2) [mmHg]					
Baseline	127.9	15.4	129.0	14.0	
After	128.3	15.2	115.3	10.8	
Change	0.4	10.8	−13.7	11.0	<0.01
Total cholesterol (X_3) [mg/dl]					
Baseline	197.0	34.4	209.0	40.9	
After	192.4	29.5	183.4	32.0	
Change	−4.5	12.4	−25.6	30.4	<0.01
Triglycerides (X_4) [mg/dl]					
Baseline	130.0	74.7	171.2	125.7	
After	111.7	74.0	84.3	69.2	
Change	−18.4	54.0	−86.9	113.0	<0.01

Stage and variable	G_E (n = 32)		G_{CE} (n = 79)		p for interaction
	Mean	SD	Mean	SD	
Subscapular skinfold thickness (X_1) [mm]					
VO_{2LT} (X_5) [ml/kg/min]					
Baseline	16.8	4.2	16.6	4.5	
After	17.6	4.1	19.3	4.9	
Change	0.9	3.6	2.7	4.8	0.056
HR_{LT} (X_6) [beat/min]					
Baseline	112.7	13.7	113.8	20.5	
After	118.5	17.7	114.0	16.2	
Change	5.9	19.4	0.2	19.9	0.176
Side stepping (X_7) [n/20 s]					
Baseline	39.7	5.4	37.7	5.6	
After	43.1	6.4	40.0	5.8	
Change	3.4	3.5	2.3	4.3	0.214
Balance (X_8) [s]					
Baseline	16.0	15.6	13.1	13.7	
After	19.9	15.6	20.2	18.1	
Change	3.9	14.4	7.0	14.2	0.297
$FEV_{1.0}$ (X_9) [L]					
Baseline	3.63	0.44	3.50	0.62	
After	3.60	0.48	3.60	0.54	
Change	–0.03	0.30	0.10	0.31	<0.05

mass (0.7% in the G_E group and 5.0% in the G_{CE} group), also noticeably decreased, except for lean mass in the G_E group (–0.6%).

Several existing studies have reported that it is difficult to achieve effective weight and fat mass reduction by exercise alone, though exercise does have a desirable influence on lean mass. Caloric restriction has a desirable influence on weight reduction and fat mass, but the decrease in lean mass is considerable. To diminish the decrease of lean mass, engaging in exercise is beneficial during caloric restriction [21, 22]. Recently, those reports have been broadly accepted as fact, and the changes in body composition in this study were consistent with the reports. Given the results from previous reports, the results in this study, and the perception that individuals with low muscle mass and high fat mass are susceptible to medical conditions, it seems that exercise alone is not an effective way to improve health status. However, Oh et al. [23] reported that exercise has a desirable influence on non-alcoholic fatty liver disease regardless of weight and fat mass reduction, and reports with similar results have been increasing in recent years [24-26]. Thus, it was recognized that a verified index, such as vital age, is essential to properly evaluate the efficiency of weight reduction programs consisting of caloric restriction and/or exercise.

Existing studies reported that the vital age before weight reduction was noticeably higher than the chronological age in both groups with obesity and groups without obesity and that the vital age in groups with obesity was higher than that in groups without obesity [19, 20]. In this study, the difference between the chronological age and vital age before weight reduction was 9.8 and 9.5 years in the G_E and G_{CE} groups, respectively. It was approximately 5 and 10 years in the report by Nakagaichi et al. [19] and Nakanishi et al. [20], respectively. Considering that subjects in this study and the study by Nakagaichi et al. [19] had BMIs of approximately 28-29 and that the subjects in the study by Nakanishi et al. [20] had BMIs of approximately 25, it was not clear that as the obesity rate increases, the vital age also increases. Based on this discrepancy, it is suggested that a vital age is not affected by a single factor such as fatness and that it reflects the comprehensive health status.

After the weight reduction programs in this study, every component of vital age in the G_E and G_{CE} groups changed to make the subjects' vital ages younger, except for SBP and $FEV_{1.0}$ in the G_E group. As a result, both groups showed noticeable improvements in vital age, and vital age in the G_{CE} group became even younger than their chronological age. Since remarkable improvement rates were detected in every component of vital age of the G_{CE} group compared to those of the G_E group, it is suggested that vital age was predominantly affected by caloric restriction and that combining exercise with caloric restriction yielded additional improvement in vital age. Interestingly, $FEV_{1.0}$ in the G_{CE} group was remarkably improved after weight reduction though it was almost unchanged in the G_E group. This may be due to the improvement in pulmonary function caused by the decreased load on the body with the reduced weight. This detection reconfirms the positive influence of caloric restriction.

There are two limitations related to this study. First, there was not a group that had weight reduction by caloric restriction only. This did not allow us to directly compare three different weight reduction programs, specifically exercise only, the caloric restriction and a combination of exercise and caloric restriction. Future studies will benefit from a study protocol that includes a caloric restriction-only weight reduction group. Second, the duration of this study was 12 weeks, which may be a rather short period to reach a definitive conclusion. It would be better to draw the findings on the influences of a weight reduction program consisting of exercise and/or caloric restriction on vital age after a longer observation period.

Regardless of the restrictions mentioned above, the results of our research are also important from the perspective of comparing the health effects (potential threats) of rapid weight reduction by athletes of various combat sports before competitions [27-29]. These periods are generally very short, and therefore the results of the method we use can be used in the practice of martial arts training – especially in the aspect of health prevention.

CONCLUSIONS

Exercise alone caused amelioration of the subscapular skinfold thickness, total cholesterol and side-stepping components of vital age, whereas every component of vital age was improved by a combination of exercise and caloric restriction. A combination of exercise and caloric restriction has stronger influences on four components of vital age, specifically SBP, total cholesterol, triglyceride and $FEV_{1.0}$, compared to exercise alone. Based on the results of this study, it is suggested that vital age was predominantly affected by caloric restriction and that combining exercise with caloric restriction yielded additional improvement in vital age.

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