Original Article

Prolonged effectiveness of 12-month exercise-plus-diet intervention in Japanese adults at risk of impaired glucose or lipid metabolism

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Background and Objectives: To investigate the prolonged effects of a 12-month exercise-plus-diet intervention in Japanese adults at risk of impaired glucose or lipid metabolism. **Methods and Study Design:** A total of 180 participants were randomly divided into an intervention group (n=94), and a control group (n=86). An exercise-plus-diet intervention was conducted on the intervention group for 12 months. The effects were evaluated by questionnaire, physical examinations, and blood tests at baseline, 3 months, 12 months (the end of intervention), and 24 months (one year after the end of intervention). The control group took only the same examinations as the intervention group. **Results:** At the end of the 12-month intervention, body weight, waist circumference, fasting glucose, HbA1c, triglycerides, and LDL-cholesterol were improved in the intervention group compared to the control group (all $p<0.05$). One year after the end of the intervention, body weight, waist circumference, fasting glucose, triglycerides, and LDL-cholesterol were still decreased in the intervention group compared to the control group (all $p<0.05$), especially among non-overweight participants. Among overweight persons, only body weight in the intervention group was lower than the control group. The personal behaviours of physical activity and diet in the intervention group were also improved. **Conclusions:** The 12-month exercise-plus-diet programs were found to be effective in improving glucose and lipid metabolism, as well as personal behaviour one year after completion of the intervention.

Key Words: intervention study, diet, exercise, prolonged effects, Japanese adults

INTRODUCTION

Personal behaviour Lifestyle-related diseases, such as diabetes, dyslipidemia, and obesity are major health problems in many countries. Previous studies have shown that behavioural lifestyle modification is necessary to prevent these diseases.[1,2] The Diabetes Prevention Program (DPP)[3] and Finnish Diabetes Prevention Study (DPS),[4] have reported that type 2 diabetes can be prevented by changing dietary habits and increasing physical activity in people with impaired glucose tolerance. Among participants with metabolic syndrome, the lifestyle intervention group showed a significantly greater reduction in weight loss and waist circumference, than the control group.[5] To investigate effective intervention, previous studies were conducted in various programs such as nutritional counseling,[6] aerobic physical exercise,[7] and combined diet and exercise education.[8,9] Many of these studies investigated effects upon completion of the intervention, though duration varied. Few studies have examined maintaining the effectiveness after the end of an intervention. In Japan, there are many non-overweight people with impaired glucose or lipid metabolism.[10] Epidemiology studies among the general Japanese population has reported that the risks of cardiovascular disease, mortality and incidence of stroke were increased in non-overweight individuals with metabolic risk factors, as well as overweight individuals with such factors.[11,12] It is important to conduct lifestyle interventions on non-overweight people with impaired glucose or lipid metabolism, as well as on overweight people, and to examine the effects of the interventions.

The present study examined the prolonged effectiveness of the behavioural lifestyle intervention in Japanese at risk of impaired glucose or lipid metabolism. We conducted a 12-month intervention to improve the behaviours lifestyles of exercise and diet ion participants including

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non-overweight people. We did not provide any intervention for one year after completion of the intervention. The purpose of this study was to investigate the lasting prolonged effects of this exercise-plus-diet intervention, by examining serum metabolisms at the end of the intervention and one year after the end of the intervention.

METHODS

Participants

Participants aged 40–69 years, who had undergone an annual health check-up conducted in 2004 in Mie Prefecture, Japan, were recruited for the study. According to the results of the health check-up, we selected 5067 residents that had been diagnosed with impaired glucose or lipid metabolism based on the following eligibility criteria: fasting blood glucose ≥110 mg/dL (not fasting, ≥140 mg/dL), glycated hemoglobin (HbA1c) ≥5.9% (measured using the National Glycohemoglobin Standardization Program (NGSP)), total cholesterol ≥220 mg/dL (women aged 50 years and over, ≥240 mg/dL), triglycerides ≥150 mg/dL or high-density lipoprotein (HDL) cholesterol <40 mg/dL. Then in 2005, all residents received an invitation letter to participate in this study. Of these, 322 participants responded that they would like to participate in the study. Among them, eleven were excluded because of the following criteria: 1) they were undergoing treatment for diabetes or dyslipidemia, 2) had a history of serious disease including cancer, cerebrovascular disease and myocardial infarction, 3) showed abnormal exercise electrocardiogram (ECG) tests, and 4) were exercising at fitness centers more than two times per week. Finally, of 311 participants, 200 were selected by simple random sampling, and randomly assigned to either the intervention group (n=100) or the control group (n=100). Upon commencement of the study, 180 participants actually participated in the study, 94 in the intervention group and 86 in the control group. All participants provided informed consent, and the study was approved by the ethics committee of the Research Center of Health, Physical Fitness and Sports, Nagoya University, and by the ethics committee of Nagoya University School of Medicine (10-140).

Intervention

The intervention group was provided with 23 lifestyle intervention sessions during the 12 months. The 1st to 12th sessions were provided once a week during the first three months. During the next 4–12 months, as the intervention interval was extended, the 13th to 23rd sessions were provided once a month. After the 12-month intervention, no intervention was provided for one year. The 1st to 12th sessions comprised exercise practice, lectures on exercise and diet that were given by a public health nurse, dietitian, and physician. In each session, participants first received a 30-min lecture about healthy diet and physical activity. The lecture covered chronic disease risk factors, well-balanced diet, choosing food, eating between meals, eating out, aerobic exercise, resistance exercise, swimming exercise, and walking. Following the lecture, participants had a 90-min exercise program comprised of a stretching exercise, aerobic exercise, and self-weight resistance exercise. The 13th, 14th, 15th, 17th, and 23rd sessions comprised a 60-min exercise program and 30-min group discussion; the 16th and 18th to 22nd sessions comprised a 90-min exercise program. These intervention programs were provided with the intervention group divided into four groups of about 25 participants. In the discussion groups, the participants were further divided into smaller groups of six to eight people, to discuss ways to maintain the recommended lifestyle modifications.

The intervention of this study was characterized by the program consisting of lectures and practices on exercise and diet. The aim of the exercise program was to persuade the participants to experience the pleasure of exercise and to become able to choose exercise that suited their lifestyle. The diet program was to understand moderate diet using food samples, cooking utensils, etc. to change their diet habits. Through the group intervention including group discussions, we also promoted mutual communication between participants to provide with mutual encouragement to maintain the recommended behavioural modifications. Our previous study has reported details of the programs, and showed effective for enhance the quality of life of each participants.[13]

Each participant received a pedometer and a specified sheet to record behavioral performance and body weight. They were instructed to measure their body weight and steps every day during the study period, and record these on a specified sheet together with whether or not they performed the targeted behaviors. All the participants in both intervention and control groups underwent medical examinations four times; at baseline, 3 months, 12 months and 24 months. The medical examinations included anthropometry, blood tests, and questionnaires. During all four medical examinations, participants within both groups received general advice about healthy diet and physical activity for the prevention of chronic disease. Hence, the control group received no intervention, but was given medical examinations and health advice based on the results of their medical examinations.

Outcome measurements

Body weight, height, waist circumference, and blood samples were examined after overnight fasting. Waist circumference was measured around the abdomen at the level of the navel at the late expiratory phase using a tape measure. Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2). Using serum samples, total cholesterol, HDL cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, serum glucose, and HbA1c were measured by a certified laboratory (Mitsubishi Chemical Medience Corporation, Yokkaichi, Japan). We measured HbA1c using a previously defined Japanese standard (Japan Diabetes Society (JDS)). The value for HbA1c (%) is estimated as an NGSP equivalent value (%) calculated by the formula HbA1c (%) = HbA1c (JDS) (%) + 0.4%.[14] Hence, we converted the measured value of HbA1c (JDS) to HbA1c (NGSP) by adding 0.4%. Physical activity was measured in steps/day using a pedometer (Yamasa EM-180, Tokyo, Japan). The participants wore the pedometer on a belt at the hip directly above the kneecap, from morning until night. A self-recorded pedometer log was maintained by each participant for seven consecutive days. Mean steps/day were calculated as the corrected total steps divided by number of days. Dietary nutrient intakes were measured based on 3-day food records. The participants were instructed to record all food eaten during the 3-day period (not to include a day with extraordinary eating). They were recommended to weigh all foods eaten. If the weight was not available, they recorded volume of foods eaten. Food records were collected after confirmation by a nutritionist. Nutrient intakes were calculated using the Standard Table of Food Composition in Japan 5th revised edition (the Science and Technology Agency of Japan).[15]

Statistical analysis

We conducted an intention-to-treat analysis. Participants who underwent four medical examinations were included in the analysis. At baseline, 180 participants (94 in the intervention group and 86 in the control group) participated in this study. Throughout the 24-month study period, 161 persons (84 in the intervention group and 77 in the control group) completed the study programs. The flow of participants through the study is shown in Figure 1. Differences between the intervention and control groups at baseline were analyzed by chi-square test and Student's t test. For comparison of changes in behavioural and clinical variables between the intervention and control groups, analysis of covariance (ANCOVA) was used, with the baseline value as a covariate. A p values <0.05 was considered statistically significant. All statistical analyses were completed using the statistical package SPSS 20.0 J for Windows.

RESULTS

Table 1 shows the baseline characteristics of participants in the intervention and control groups. There were no significant differences between the two groups. Mean BMI at baseline was 22.7 kg/m^2 in the intervention group and 22.9 kg/m^2 in the control group. The prevalence of overweight (BMI ≥25 kg/m^2) at baseline was 14.3 % in the intervention group and 19.5 % in the control group. At 3 months, four participants (one in the intervention group and three in the control group) were treated for hyperlipidemia. At 12 and 24 months, three participants (one in the intervention group and two in the control group) were treated for hyperlipidemia. The participants were excluded from the analyses of the lipid parameters, in order not to reflect impact by medical treatment. In the meantime, no one was treated for diabetes during the study.

Table 2 shows the changes in anthropometric and clinical parameters from baseline to 3, 12 and 24 months respectively. At 3 months, body weight (p<0.001), waist circumference (p<0.001), HbA1c (p=0.006), triglycerides (p=0.001), and LDL cholesterol (p=0.042) decreased significantly in the intervention group compared with the

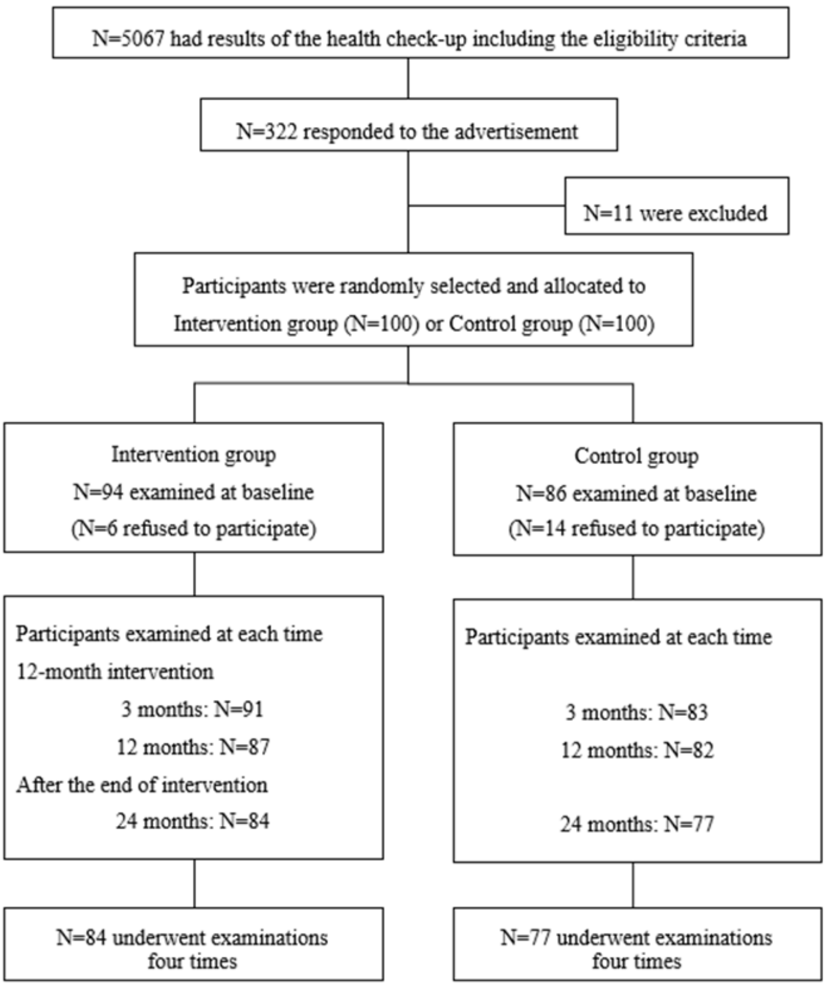

Figure 1. Flow chart showing how participants were selected, randomized, and observed.

Table 1. Baseline characteristics of study participants

	Intervention group (n=84)		Control group (n=77)		$p^{\dagger}$
	Mean	SD	Mean	SD	
Age	62.8	4.5	63.0	4.8	0.876
Sex, n (%)					
Men	29	34.5	27	35.1	1.000‡
Women	55	65.5	50	64.9	
Weight (kg)	56.6	8.4	57.5	10.8	0.571
BMI (kg/m^2)	22.7	2.3	22.8	2.7	0.713
Waist circumference (cm)	85.3	7.1	84.6	9.1	0.623
Overweight (BMI ≥25 kg/m^2), n (%)					
Non-overweight	72	85.7	62	80.5	0.479‡
Overweight	12	14.3	15	19.5	
Fasting glucose (mg/dL)	95.7	13.4	92.7	13.1	0.157
HbA1c (%)	5.4	0.5	5.5	0.4	0.255
Triglycerides (mg/dL)	108	45.7	122	60.4	0.118
HDL-cholesterol (mg/dL)	57.6	12.6	56.7	14.6	0.680
LDL-cholesterol (mg/dL)	150	29.0	145	26.2	0.311
Mean steps/day	6882	2527	7429	3023	0.133
Energy (kcal/day)	2085	444	2074	407	0.612
Protein (% energy)	15.1	2.5	14.8	2.4	0.406
Fat (% energy)	23.5	6.2	25.1	6.9	0.112
Carbohydrates (% energy)	58.1	7.1	57.4	7.7	0.599
Fiber (g/day)	17.1	5.8	18.2	5.6	0.199

Data are expressed as mean (standard deviation: SD) unless otherwise noted.
†*p* values by Student's t test; ‡ *p* values by chi-square test.

Table 2. Changes in anthropometric and clinical parameters

	From baseline to 3 months			From baseline to 12 months			From baseline to 24 months		
	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$
Weight (kg)									
Intervention	-1.42	1.25	<0.001	-1.96	1.92	<0.001	-1.91	2.02	<0.001
Control	-0.13	1.19		-0.40	1.78		-0.66	1.78	
Waist circumference (cm)									
Intervention	-1.95	2.70	<0.001	-2.01	3.21	<0.001	-2.54	3.30	<0.001
Control	0.83	2.95		0.94	3.42		0.60	3.77	
Fasting glucose (mg/dL)									
Intervention	-3.88	9.35	0.052	-4.45	9.23	<0.001	-1.52	9.29	0.001
Control	-0.17	9.89		1.24	8.83		4.70	12.1	
HbA1c (%)									
Intervention	-0.02	0.24	0.006	0.05	0.22	0.002	0.16	0.26	0.103
Control	0.06	0.19		0.15	0.18		0.22	0.23	
Triglycerides (mg/dL)‡									
Intervention	-16.2	39.4	0.001	-2.48	48.7	0.029	-9.02	44.6	0.020
Control	-5.22	42.4		7.23	45.4		-2.28	50.1	
HDL cholesterol (mg/dL)‡									
Intervention	-0.46	7.81	0.262	0.58	7.67	0.115	3.18	8.26	0.213
Control	1.05	7.51		-1.05	7.20		1.84	8.24	
LDL cholesterol (mg/dL)‡									
Intervention	-10.6	20.9	0.042	-9.57	22.0	0.006	-11.8	21.2	0.041
Control	-3.10	20.0		0.23	18.4		-4.07	19.3	

Data are expressed as mean (standard deviation: SD).
†*p* values by ANCOVA adjusting for baseline value.
‡Participants with hyperlipidemia were excluded from analysis.

control group. In addition, at 12 months, fasting glucose also significantly decreased compared with the control group ($p<0.001$). Increase in HbA1c in the intervention group was significantly lower than in the control group at 12 months ($p=0.002$). At 24 months, body weight ($p<0.001$), waist circumference ($p<0.001$), fasting glucose ($p=0.001$), triglycerides ($p=0.020$), and LDL cholesterol ($p=0.041$) in the intervention group continued to significantly decrease compared with the control group.

Table 3 shows the changes in daily step counts and dietary intakes from baseline to 3, 12, and 24 months respectively. In the intervention group, daily step counts increased significantly compared to the control group at 3, 12, and 24 months (all $p<0.001$). Energy intake and carbohydrate intake in the intervention group decreased compared with the control group at 3 months ($p=0.012$ and $p=0.019$, respectively). Besides, fiber intake significantly increased more than the control group at 24 months

Table 3. Changes in daily step counts and dietary intakes

	From baseline to 3 months			From baseline to 12 months			From baseline to 24 months		
	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$
Mean steps/day									
Intervention	2357	2192	<0.001	2282	2678	<0.001	2459	2749	<0.001
Control	282	2298		-367	1749		-234	2099	
Energy (kcal/day)									
Intervention	-228	509	0.012	-175	478	0.301	-180	480	0.991
Control	-60.5	411		-97.8	467		-173	506	
Protein (% energy)									
Intervention	0.97	3.46	0.880	0.60	3.51	0.795	1.27	3.35	0.304
Control	1.18	3.82		0.96	3.32		1.05	3.64	
Fat (% energy)									
Intervention	-1.08	7.08	0.066	-2.06	7.67	0.081	-1.85	7.33	0.775
Control	-0.08	7.71		-1.92	8.81		-2.84	7.67	
Carbohydrates (% energy)									
Intervention	1.27	8.71	0.019	2.28	8.38	0.244	1.52	7.82	0.813
Control	-1.09	8.79		1.42	8.58		2.12	8.04	
Fiber (g/day)									
Intervention	1.26	6.83	0.299	1.56	6.62	0.493	1.89	6.46	0.011
Control	-0.45	6.46		0.20	7.18		-1.03	6.32	

Data are expressed as mean (standard deviation: SD).
$^{\dagger}p$ values by ANCOVA adjusting for baseline value.

(p=0.011).

Table 4 shows the changes in anthropometric and clinical parameters from baseline to 3, 12, and 24 months respectively among participants who were non-overweight (BMI <25 kg/m^2) and overweight (BMI ≥25 kg/m^2) at baseline. Among non-overweight participants (n=72 in the intervention group and n=62 in the control group), body weight, waist circumference, fasting glucose, and triglycerides in the intervention group decreased significantly compared with the control group at 12 (p<0.001, p<0.001, p=0.001 and p=0.004, respectively) and 24 months (p=0.001, p<0.001, p=0.003 and p=0.027, respectively). Increase in HbA1c in the intervention group was lower than in the control group at 12 months (p=0.014). Among overweight participants (n=12 in the intervention group and n=15 in the control group), body weight (p=0.007), waist circumference (p=0.010), HbA1c (p=0.026) and LDL cholesterol (p=0.023) were lower in the intervention group compared with the control group at 12 months. At 24 months, body weight in the intervention group was still lower than the control group (p=0.021).

DISCUSSION

In the present study, we conducted a 12-month exercise-plus-diet intervention on Japanese adults at risk of impaired glucose or lipid metabolism. At the end of the 12-month intervention, participants in the intervention group showed beneficial effects on glucose and lipid metabolisms. They demonstrated decreases in body weight, waist circumference, fasting glucose, triglycerides, and LDL cholesterol compared to participants in the control group. Increases in HbA1c were significantly lower in the intervention group was than the control group. In addition, this study showed that the intervention group maintained the beneficial effects of body weight, waist circumference, fasting glucose, triglycerides, and LDL-cholesterol, one year after completing the intervention.

Multiple earlier studies reported that lifestyle intervention was effective in improving the glucose or lipid metabolism,[2,9,16-18] and in particular, exercise plus diet intervention.[1,19] A systematic review reported that combined diet plus exercise (both aerobic and resistance training) interventions conducted in at-risk or prediabetic adults were modestly effective in inducing weight loss and improving impaired fasting glucose, glucose tolerance, and improving dietary and exercise outcomes.[1] Our results, which support the benefits of reducing body weight, improving serum lipid and glucose, combined with exercise-plus-diet intervention, are consistent with prior studies.[1,2] One interesting finding of our study is the improvement of serum lipid and glucose in non-overweight participants. The baseline mean BMI was within normal range (22.7 kg/m^2 in the intervention group and 22.9 kg/m^2 in the control group), whereas participants of earlier studies were overweight or obese. Therefore, the mean weight reduction at the end of our intervention was modest (-1.96 kg), and lower than that observed after 12 month in the studies which provided the combined diet plus exercise intervention, such as DPS (-4.5 kg),[17] the Study on Lifestyle intervention and Impaired glucose tolerance Maastricht (SLIM) (-2.77 kg),[20] and the meta-analysis study (-3.79 kg; median intervention length was 12 months with a follow-up of 18 months).[1] However, our study showed improvement in serum glucose and lipid, which is consistent with previous studies.[1,17,20] In addition, among non-overweight participants, we observed improvements in fasting glucose, HbA1c, triglycerides, and HDL-cholesterol in the intervention group compared with the control group. We believe that the interventions in this study were effective for both overweight and non-overweight participants.

HbA1c in intervention group was not decreased at 12 months. Japanese population are generally characterized by a decreased capacity for insulin secretion owing to reduced pancreatic β cell function compared with Western populations,[21] so that Japanese are considered to be at greater risk for impaired glucose metabolism, even in individuals with non-overweight.[22] Earlier studies ex-

Table 4. Changes in anthropometric and clinical parameters among non-overweight and overweight participants at baseline

	Baseline		From baseline to 3-month			From baseline to 12-month			From baseline to 24-month		
	Mean	SD	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$	Mean	SD	$p^{\dagger}$
Non-overweight (BMI <25 kg/m^2)											
Weight kg											
Intervention	54.7	6.84	-1.28	1.13	<0.001	-1.75	1.75	<0.001	-1.77	1.93	0.001
Control	54.1	7.82	-0.09	1.28		-0.32	1.82		-0.67	1.78	
Waist circumference (cm)											
Intervention	83.7	6.04	-1.90	2.84	<0.001	-1.95	3.22	<0.001	-2.61	3.09	<0.001
Control	81.8	7.00	0.94	3.20		1.06	3.74		0.58	4.02	
Fasting glucose (mg/dL)											
Intervention	95.6	14.1	-3.78	9.88	0.140	-4.28	9.68	0.001	-1.19	9.56	0.003
Control	91.6	12.8	-0.11	8.33		1.34	6.50		4.21	7.70	
HbA1c (%)											
Intervention	5.38	0.48	-0.01	0.23	0.014	0.08	0.21	0.014	0.18	0.25	0.379
Control	5.44	0.41	0.07	0.20		0.16	0.18		0.21	0.18	
Triglycerides (mg/dL)‡											
Intervention	108	44.9	-15.7	39.0	0.005	-5.04	42.5	0.004	-11.7	42.5	0.027
Control	111	49.6	-1.78	36.8		13.2	41.0		1.14	45.3	
HDL cholesterol (mg/dL)‡											
Intervention	58.2	12.3	-0.45	8.06	0.375	0.59	8.04	0.047	3.62	7.71	0.185
Control	58.5	14.6	0.64	7.37		-2.00	6.56		1.75	8.31	
LDL cholesterol (mg/dL)‡											
Intervention	151	29.3	-10.4	20.6	0.105	-8.92	21.9	0.068	-12.3	21.2	0.071
Control	145	25.1	-3.47	19.6		-1.05	18.8		-4.36	19.1	
Overweight (BMI ≥25 kg/m^2)											
Weight kg											
Intervention	67.6	8.86	-2.29	1.63	<0.001	-3.23	2.42	0.007	-2.74	2.42	0.021
Control	71.2	10.6	-0.27	0.70		-0.73	1.61		-0.65	1.80	
Waist circumference (cm)											
Intervention	93.9	7.20	-2.27	1.67	<0.001	-2.38	3.29	0.010	-2.09	4.52	0.064
Control	96.6	6.47	0.35	1.55		0.47	1.53		0.68	2.59	
Fasting glucose (mg/dL)											
Intervention	95.9	9.56	-4.50	5.37	0.160	-5.50	6.11	0.058	-3.50	7.55	0.081
Control	97.7	13.9	-0.40	15.1		0.80	15.4		6.67	22.9	
HbA1c (%)											
Intervention	5.43	0.34	-0.09	0.27	0.164	-0.08	0.28	0.026	0.07	0.29	0.186
Control	5.61	0.45	0.00	0.16		0.14	0.16		0.29	0.38	
Triglycerides (mg/dL)‡											
Intervention	110	53.8	-19.3	43.2	0.056	12.7	77.0	0.660	6.75	54.9	0.436
Control	173	73.9	-19.7	60.4		-18.5	55.6		-15.7	65.9	
HDL cholesterol (mg/dL)‡											
Intervention	54.4	14.9	-0.50	6.43	0.558	0.50	5.25	0.751	0.58	11.0	0.477
Control	47.3	9.66	2.79	8.14		3.00	8.58		2.20	8.23	
LDL cholesterol (mg/dL)‡											
Intervention	138	22.4	-12.1	23.4	0.126	-13.4	23.4	0.023	-8.58	21.4	0.370
Control	142	23.1	-1.50	22.6		5.71	16.1		-2.93	20.8	

Data are expressed as mean (standard deviation: SD).
†*p* values by ANCOVA adjusting for baseline value.
‡Participants with hyperlipidemia were excluded from analysis.

amined the changes in HbA1c levels in Japanese general population within about 10 years, and reported that the HbA1c levels increased year by year.[22,23] Especially, significant increase in HbA1c was shown in people at risk of impaired glucose metabolism, similar to participants of our study.[22] However, this study showed that an increase in HbA1c was lower in the intervention group than in the control group. We considered that the intervention contributed to the long-term stability of HbA1c.

This study also demonstrated the prolonged beneficial effects of an exercise-plus-diet intervention. Even though no additional interventions were conducted for 12 months after intervention, the intervention group maintained beneficial effects on body weight, waist circumference, fasting glucose, triglycerides, and LDL cholesterol. Some studies have investigated the effects that occur after an intervention is completed.[5,18,24-26] Brekke et al[26] provided a healthy diet and exercise intervention and intensive follow-up during the first four months among healthy participants who were non-diabetic first-degree relatives of type 2 diabetic patients, and demonstrated a 2-year sustainability on blood lipids and fasting insulin. McLaughlin et al[24] conducted a 16-week nutritional intervention for obese participants, and showed a reduction in body weight and triglycerides together with an increase in HDL cholesterol two or three years after the end of intervention, compared to baseline levels. However, several studies reported difficulty in maintaining the effects of intervention.[5,18,25] Swinburn et al[18] conducted a 1-year intervention but reported the failure to maintain reduction in fasting glucose, 2-h glucose, and body weight at two, three and five years after the investigation compared with the baseline. Oh et al[5] examined the effects of 6-month therapeutic lifestyle modification (TLM) program for middle-aged and older women with metabolic syndrome (MetS) at baseline, during the study (3-month), at completion (6-month) and post-completion (12-month) of the TLM program. TLM group showed significantly greater reductions in body weight and waist circumference, and these effects were sustained for 6 months after intervention (at post-completion). However, that intervention did not show significant effects on other components of MetS, such as systolic and diastolic blood pressure, fasting glucose, HDL-cholesterol, and triglycerides. In our study, participants in the intervention group maintained the beneficial effects of body weight, lipid and glucose concentrations one year after the end of the intervention. They also maintained better exercise and diet behaviours: the intervention group showed significantly improved physical activity, decreased energy intake, and increased fiber intake compared to baseline. This intervention could therefore improve exercise and diet behaviours, leading to prolonged beneficial effects of body weight, lipid and glucose concentrations.

The 12-month exercise-plus-diet intervention aimed to improve exercise and diet behaviours, increase regular physical activities, and promote healthy diets. There are probably at least three factors in this study that contributed to the sustained improvement of exercise and diet. First, this program was comprised of two parts, exercise practice and lectures on exercise and healthy diet. Combined intervention with diet and exercise is effective in preventing obesity compared with intervention of either diet or exercise alone.[9,19,26] Therefore, participants may have achieved behavioural modification with combined dietary changes and increased physical activity. Second, we conducted the group intervention to promote mutual communication throughout the program. Several studies have reported that group intervention was effective for lifestyle improvement.[27-29] Yokoyama et al[29] reported that group programs brought a high sense of achievement and satisfaction to participants compared with individual programs. Participants in the intervention group increased their intimacy with other members in the group, and enjoyed practicing the program with members. This might have motivated them to change their lifestyle. Third, we provided an intensive intervention program once a week during the first three months, and then a follow-up intervention program once a month during the following nine months. These follow-up sessions helped participants to monitor their own lifestyle. They could also obtain advice and encouragement from group members during group discussion at follow-up sessions. These measures were probably effective in maintaining long-term improvements in lifestyle.

Our results could not show the effects of intervention for overweight participants. Approximately 5% weight reduction is reported to improve metabolic parameters in obese.[30-32] A study, which conducted the 6-month lifestyle modification program for Japanese obese people, reported that weight reduction of at least ≥3% improved of parameters of obesity-related diseases.[30] In addition, the Japan Society for the Study of Obesity (JASSO) has recommended 3 kg reduction in body weight or 3 cm reduction in waist circumference for the prevention or improvement of metabolic syndrome. Overweight participants in our study may have been lack of body weight or waist circumference reduction to improve metabolic syndrome.

The present study had some limitations. Since the study was limited to participants from one health check-up in central Japan, the results cannot be generalized to other populations. In addition, among 180 participants at baseline, 161 participants underwent medical examinations throughout the 24 months. Participants who did not undergo medical examination four times were excluded from this analysis. The participants excluded from this study showed no significant differences in baseline anthropometric and clinical parameters compared with the 161 participants.

Conclusion

We conducted a 12-month exercise-plus-diet intervention on Japanese adults at risk of impaired glucose or lipid metabolism. At the end of the 12-month intervention, participants in the intervention group showed beneficial effects on glucose and lipid metabolism. Moreover, these effects were maintained for one year after the intervention. We propose that this intervention could improve exercise and dietary behaviours, and lead to prolonged beneficial effects on glucose and lipid metabolism. In addition, these benefits were observed in non-overweight participants. These findings suggest that it is beneficial to provide behavioural interventions for non-overweight people at risk of impaired metabolism.

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AUTHOR DISCLOSURES

The authors declare that they have no conflict of interest and funding.

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