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Effects of lifestyle modification on metabolic parameters and carotid intima-media thickness in patients with type 2 diabetes mellitus

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Abstract

The aim of this study was to examine the effects of a 6-month intensive lifestyle modification intervention on metabolic parameters and carotid intima-media thickness (IMT) in patients with type 2 diabetes mellitus. Fifty-eight subjects with type 2 diabetes mellitus were randomly assigned to the intervention group or the control group. The subjects in the intervention group participated in a 16-week intensive lifestyle modification program and subsequent monthly meetings during the 6-month study period. Control subjects received basic dietary education and usual care. Anthropometric data, metabolic parameters, and carotid IMT were examined before the intervention and after 6 months. Lifestyle modification intervention group patients showed a significant reduction in HbA_{1c} (−1.0% ± 1.3% vs +0.1% ± 1.2%, P = .002), fasting blood glucose (−1.6 ± 1.5 vs +0.3 ± 2.5 mmol/L, P = .001), and 2-hour postprandial plasma glucose (−2.1 ± 2.5 vs +0.8 ± 4.4 mmol/L, P = .003) compared with control patients after 6 months. Body weight (−2.0 ± 2.6 vs +0.2 ± 1.7 kg, P = .001), body mass index (−0.8 ± 1.0 vs 0.0 ± 0.8 kg/m^2, P = .003), and systolic blood pressure (−8.2 ± 15.9 vs +0.4 ± 14.1 mm Hg, P = .041) were significantly decreased in the intervention group. A significantly reduced carotid mean IMT progression was seen in the intervention group after 6 months (−0.040 ± 0.136 vs +0.083 ± 0.167 mm, P = .007). Changes in HbA_{1c} (r = 0.34, P = .028), fasting plasma glucose (r = 0.31, P = .045), and 2-hour postprandial plasma glucose (r = 0.37, P = .015) correlated with the mean carotid IMT change after adjustment for age and sex. In conclusion, a 6-month intensive lifestyle modification intervention in patients with type 2 diabetes mellitus resulted in improved glycemic control and decreased progression of carotid IMT.

1. Introduction

Type 2 diabetes mellitus is a rapidly growing chronic health problem, and the accompanying long-term microvascular and macrovascular complications cause significant morbidity and mortality in patients with diabetes. The onset and progression of atherosclerosis are much more rapid in individuals with diabetes than in those without diabetes. The increased prevalence of cardiovascular disease in patients with diabetes is preceded by a constellation of risk factors including dyslipidemia, hypertension, and obesity [1]. These risk factors, together with hyperglycemia itself, act in concert to create a very potent atherogenic situation, resulting in catastrophic results such as acute myocardial infarction or stroke [2]. Tight glycemic control, weight loss, the improvement of insulin resistance, and the correction of dyslipidemia contribute to the prevention of atherosclerosis in patients with diabetes [3].

Lifestyle is known to be an important factor in glycemic control and the development and progression of atherosclerosis. The Lifestyle Heart Trial and subsequent studies showed that lifestyle changes could lead to a reduction in the atherosclerotic progression of the coronary artery [4,5]. Ultrasound measurement of the carotid intima-media thick-

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ness (IMT) is a reliable measure of early atherosclerosis. [6,7]. Several studies have shown that increased carotid IMT confers risk of future coronary heart disease and stroke [8-10]. There are conflicting results on the effects of lifestyle modification on carotid IMT in nondiabetes [11-16]. However, to our knowledge, there have been no previous studies examining the effects of lifestyle modification on carotid IMT in type 2 diabetes mellitus. In this study, we examined the effects of a 6-month intensive lifestyle modification intervention on glycemic control, blood pressure, dyslipidemia, obesity, and carotid IMT in patients with type 2 diabetes mellitus.

2. Materials and methods

2.1. Study subjects

Fifty-eight subjects with type 2 diabetes mellitus were recruited from the outpatient clinic at the Yonsei University Severance Hospital Diabetes Center (Seoul, Korea). Diabetes was defined according to the 1997 American Diabetes Association diagnostic criteria [17]. The inclusion criteria for patients were as follows: (1) treatment with oral hypoglycemic agents or diet and exercise alone, not with insulin therapy; (2) HbA_{1c} level of higher than 7.0%; (3) no change in any medications for the past 3 months; and (4) no history of ketoacidosis. Patients with congestive heart failure (New York Heart Association II-IV), a recent episode of ischemic heart disease, peripheral vascular disease, current malignancy, chronic renal failure, severe proliferative diabetic retinopathy, or any physical and mental conditions that may have influenced the ability of the patient to participate in the intervention were excluded. The study protocol was approved by the institutional review board of Yonsei University College of Medicine. All patients gave informed consent to participate in this study.

2.2. Intervention

Participants were randomly assigned to the intensive lifestyle intervention group or the control group. Nonessential changes in medication and dosage that might affect the study outcome were not made. The goals for the participants assigned to the intensive lifestyle intervention were to achieve and maintain a modest weight loss (5% of the initial weight in obese subjects), follow a recommended dietary intake, and undertake physical activity of moderate intensity, such as brisk walking, for at least 150 min/wk.

A 16-lesson curriculum covering diet, exercise, and behavior modification was designed to help the participants achieve these goals. The curriculum was individualized and taught by case managers, consisting of 2 skilled nurses and 1 exercise trainer, on a one-on-one basis. During the first 4 weeks, the brisk walking time was increased gradually, and from the second month, considering the individual patient's status, the aim was individualized to 3 to 12 hours of brisk walking, hiking, or swimming per week. Patients were asked to exercise at the Rating Perceived Exertion level 12 to 14, which is the subjective intensity of a "from a little bit strenuous to hard," and to exercise within the range of 40% to 60% of the maximum exercise capacity by measuring pulse rate during exercise. Energy intake was assessed weekly by recording food intake for 2 days. The lessons were given weekly for 16 weeks, and participants attended subsequent monthly educational sessions for reinforcement of the lifestyle modifications during the remainder of the 6-month study period. The control subjects continued their usual medical care and were given 1 session of dietary counseling at the beginning of the study period. Subjects were asked by their physicians to follow these guidelines and to increase physical activity during their regular hospital visit (every 3 months).

2.3. Outcome measures

Laboratory data, blood pressure, and anthropometric measurements were collected for each patient at baseline and after 6 months (at the end of the study). Fasting blood samples were obtained to measure the concentrations of plasma glucose, serum total cholesterol, serum triglycerides, high-density lipoprotein cholesterol (HDL-C), and HbA_{1c} using standard laboratory techniques. The low-density lipoprotein cholesterol (LDL-C) level was calculated using the Friedewald formula [18]. The insulin concentration was measured using a radioimmunoassay kit (DAINABOT, Tokyo, Japan). The homeostasis model assessment of insulin resistance ($HOMA_{IR}$) was calculated by the following formula: (fasting insulin [μU/mL] $\times$ fasting glucose [mmol/L])/22.5 [19]. Serum high-sensitivity CRP (hsCRP) levels were measured by a latex-enhanced immunonephelometric assay method using a BN II Nephelometer Analyzer (Dade Behring, Newark, DE). Microalbuminuria was defined as album-to-creatinine ratio exceeding 30 mg/g of creatinine in a random urine sample. Urinary albumin was measured by immunonephelometry (Behring Nephelemetry analyzer II, Behringwerke, Marburg, Germany), and creatinine was analyzed by Jaffe reaction (CX3, Beckman, Brea, CA). Body weight, height, and waist and hip circumference, and blood pressure were measured at baseline and after 6 months by a medical personnel who was unaware of the patient's status. Blood pressure was measured after 30 minutes of rest in the sitting position.

2.4. Carotid B-mode ultrasound measurement

Ultrasonography of the common carotid artery (CCA) was conducted bilaterally by high resolution B-mode ultrasonography (LOGIQ9, GE Medical Systems, Milwaukee, WI) with a 10-MHz linear transducer at baseline and after 6 months by a single sonographer who was unaware of the subject's characteristics as previously described [20,21]. Computer-assisted acquisition, processing, storage of B-mode images, and calculation of IMT were performed with the software Intima Scope (MediaCross, Tokyo, Japan). The software estimated lines for the lumen-intima interface and the media-adventitia interface based on 30-point pixels per 3 mm obtained from the tertiary multiple regression analysis incorporating the least square method, which was designed to achieve increased accuracy and reproducibility with reduced variability for the measurements of IMT [22]. Measurements from the left and right CCAs were made at the far walls of the 20-mm segment distal to the carotid bulbs. Reading and analysis of images were done by a single well-trained physician who was blinded to the identity of the patient, time point, and treatment at the end of the study. The intraobserver coefficient of variance was 2.1%.

2.5. Statistical analyses

Data are shown as means ± SD. All calculations and statistical analyses were performed using the SPSS for Windows software (version 11.5; SPSS, Chicago, IL). Baseline comparisons were assessed by independent sample *t* tests or χ^2, as appropriate. Repeated-measures analysis of variance was used to compare the change in fasting plasma glucose, 2-hour postprandial plasma glucose (2h PPG), and HbA_{1c} between the groups. Independent *t* tests or Mann-Whitney tests were used to analyze the differences between the intervention and control groups in changes from baseline to end-point measurements, and changes within the groups were analyzed by paired *t* tests. Partial correlation was used to assess the correlation between 2 variables when adjusting for age and sex. Linear regression analysis was used to assess the influence of other baseline demographic or clinical parameters on mean CCA IMT change. Statistical analysis of triglycerides, hsCRP, $HOMA_{IR}$, and HDL-C were performed using log-transformed values because the distribution was not normal. Results were considered statistically significant if the *P* value was less than .05.

3. Results

3.1. Baseline characteristics

Baseline clinical and demographic characteristics did not differ significantly between the intervention and control groups (Table 1). Overall, subjects had a mean age of 54.4 years, a diabetes duration of 8.8 years, and an HbA_{1c} of 8.8%. Seventy-six percent of the participants were women, and 57% of the participants were obese (defined as body mass index [BMI] ≥25 kg/m^2 [23]).

3.2. Compliance and adherence to the intensive lifestyle modification intervention

Adherence to the intervention program was judged by attendance of the 16-lesson curriculum during the first 16 weeks of the intervention. Weekly physical activity, achievement of the daily energy intake goal, and the degree of weight loss were also assessed. The mean attendance for the 16-lesson curriculum was 75%. Baseline mean physical activity was 2.9 h/wk, and 50% of the subjects had baseline physical activity of less than 150 min/wk. After 3 months, physical activity significantly increased, and this increase was maintained until the end of the study period (9 and 8.6 h/wk at 3 and 6 months, respectively). Except for 1 participant, all participants in the intervention group achieved the physical activity goal. Although only 5 subjects achieved their daily energy intake goals at 3 months, and none did so at the end of the study, the overall daily energy intake decreased from baseline by a mean (±SD) of 1867 ± 121 kJ at 3 months and 1347 ± 109 kJ at the end of the study.

Table 1
Baseline characteristics of subjects in the intervention and control group

Characteristics	Intervention group	Control group	*P*
n (male/female)	32 (6/26)	26 (8/18)	.29
Current smokers (n)	4	6	.31
Age (y)	55.0 ± 8.1	53.8 ± 9.0	.61
Diabetes duration (y)	7.9 ± 6.5	10.0 ± 6.6	.23
Weight (kg)	65.7 ± 13.5	66.6 ± 13.9	.82
BMI (kg/m^2)	25.8 ± 3.8	26.2 ± 4.0	.73
Fasting plasma glucose (mmol/L)	9.1 ± 2.1	9.3 ± 1.8	.75
2h PPG (mmol/L)	12.8 ± 3.1	13.6 ± 3.7	.36
HbA_{1c} (%)	8.5 ± 1.4	8.6 ± 1.3	.84
Total cholesterol (mmol/L)	5.2 ± 1.0	4.9 ± 0.9	.21
HDL-C (mmol/L)	1.3 ± 0.3	1.3 ± 0.2	.57
LDL-C (mmol/L)	3.4 ± 0.8	3.1 ± 0.9	.29
Triglyceride (mmol/L)	1.7 ± 0.8	1.8 ± 1.1	.91
$HOMA_{IR}$	2.6 ± 1.4	2.6 ± 1.5	.97
HsCRP (mg/L)	0.8 ± 0.8	1.3 ± 1.4	.10
Systolic blood pressure (mm Hg)	130.3 ± 14.5	132.7 ± 17.8	.58
Diastolic blood pressure (mm Hg)	84.8 ± 9.5	81.1 ± 7.3	.12
Mean carotid IMT (mm)	0.705 ± 0.143	0.681 ± 0.201	.62
Microalbuminuria (n)	6	8	.27
No. of diabetes medications per day	1.5 ± 1.0	1.9 ± 1.0	.09
Biguanides (%)	63	81	.13
Sulfonylurea (%)	59	69	.44
Thiazolidinediones (%)	22	35	.28
Other diabetic medications (%)	3	8	.58
Use of antihypertensive medications (%)	50	38	.38
ARB or ACEi (%)	25	19	.60
Use of aspirin (%)	13	12	1.0
Use of lipid-lowering medications (%)	19	19	.96

Data are means ± SD unless otherwise indicated. ARB indicates angiotensin receptor blocker; ACEi, angiotensin-converting enzyme inhibitor.

3.3. Glycemic and metabolic outcomes

Lifestyle modification intervention group patients showed a significant reduction in HbA_{1c}, fasting blood glucose, and 2h PPG after 6 months. Differences between groups in changes of fasting plasma glucose, 2h PPG, and HbA_{1c} were also significant at 3 months. For total cholesterol, HDL-C, LDL-C, serum triglyceride concentrations, and $HOMA_{IR}$, the differences in changes between the intervention and control groups from baseline to the

Table 2
Changes in clinical and metabolic parameters in the intervention and control groups

Variable	Intervention group (n = 32)			Control group (n = 26)			P^a
	Baseline	6 mo	Change[b]	Baseline	6 mo	Change[b]	
Body weight (kg)	65.7 ± 13.5	63.7 ± 12.8	−2.0 ± 2.6	66.6 ± 13.9	66.5 ± 14.0	0.0 ± 1.7	.001
BMI (kg/m^2)	25.8 ± 3.8	25.1 ± 3.5	−0.8 ± 0.9	26.2 ± 4.1	26.2 ± 4.2	0.0 ± 0.7	.001
Waist circumference (cm)	87.7 ± 9.6	84.5 ± 9.6	−3.3 ± 2.9	90.6 ± 11.3	88.3 ± 12.2	−2.3 ± 3.4	.74
Waist-to-hip ratio	0.89 ± 0.05	0.87 ± 0.05	−0.02 ± 0.02	0.89 ± 0.05	0.88 ± 0.07	−0.01 ± 0.04	.31
HbA_{1c} (%)	8.5 ± 1.4	7.6 ± 0.9	−1.0 ± 1.2	8.6 ± 1.3	8.7 ± 1.3	0.1 ± 1.2	.002
FPG (mmol/L)	9.1 ± 2.1	7.5 ± 1.5	−1.6 ± 1.5	9.3 ± 1.8	9.6 ± 2.6	0.3 ± 2.5	.001
2h PPG (mmol/L)	12.8 ± 3.1	10.7 ± 3.1	−2.1 ± 2.5	13.6 ± 3.7	14.4 ± 4.3	0.8 ± 4.4	.005
Total cholesterol (mmol/L)	5.2 ± 1.0	5.0 ± 0.8	−0.2 ± 0.8	4.9 ± 0.9	4.9 ± 0.9	0.0 ± 0.6	.36
HDL-C (mmol/L)	1.3 ± 0.3	1.3 ± 0.3	0.0 ± 0.2	1.3 ± 0.2	1.3 ± 0.3	0.0 ± 0.2	.55
LDL-C (mmol/L)	3.4 ± 0.8	3.2 ± 0.7	−0.2 ± 0.8	3.1 ± 0.9	2.9 ± 0.7	−0.2 ± 0.5	.77
Triglyceride (mmol/L)	1.7 ± 0.8	1.6 ± 0.7	−0.1 ± 0.7	1.8 ± 1.1	2.5 ± 3.3	0.7 ± 2.6	.08
$HOMA_{IR}$	2.6 ± 1.4	2.6 ± 1.5	0.0 ± 1.3	2.5 ± 1.5	3.2 ± 2.5	0.6 ± 2.1	.16
Systolic BP (mm Hg)	130.3 ± 14.5	122.1 ± 11.6	−8.2 ± 15.9	132.7 ± 17.8	133.1 ± 15.1	0.4 ± 14.1	.04
Diastolic BP (mm Hg)	84.8 ± 9.5	80.2 ± 8.4	−4.6 ± 10.7	81.1 ± 7.3	80.3 ± 8.4	−0.9 ± 7.7	.15
HsCRP (mg/L)	0.8 ± 0.8	0.6 ± 0.6	−0.2 ± 0.6	1.3 ± 1.4	1.1 ± 1.1	−0.3 ± 1.0	.68
Mean carotid IMT (mm)	0.714 ± 0.138	0.664 ± 0.124	−0.040 ± 0.136	0.678 ± 0.205	0.761 ± 0.147	0.083 ± 0.167	.007

Data are means ± SD. FPG indicates fasting plasma glucose; BP, blood pressure.
[a] P values were determined by a comparison of the change in each variable between the intervention and control groups.
[b] Change is the absolute change in variables from baseline to end point (at 6 months) in each group.

end of the study were small and not statistically significant (Table 2).

3.4. Physical outcomes

Mean weight change differed significantly between the intervention group and the control group (P = .001). After 6 months, the participants in the intervention group lost an average of 2.0 ± 2.6 kg (2.8% ± 3.0% weight loss from baseline), whereas the participants in the control group had no change in weight (0.0 ± 1.7 kg). Twenty-five percent of the participants in the intervention group achieved 5% weight loss and only 1 participant achieved 10% weight loss at the end of the study period. None of the participants in the control group achieved 5% weight loss. The mean BMI decreased 0.8 ± 0.9 kg/m^2 in the intervention group and did not change in the control group (P = .001; Table 2). The change in waist-to-hip ratio was not significantly different between the 2 groups. However, waist-to-hip ratio decreased significantly (0.89 ± 0.05 at baseline vs 0.87 ± 0.05 after 6 months, P < .01) within the intervention group, but not in the control group.

Table 3
Multiple linear regression analyses with change in mean IMT as a dependent variable and baseline clinical characteristics and lifestyle modification intervention as independent variables

	β	P
Sex[a]	.315	.15
Age	.100	.56
Duration of diabetes	−.161	.47
Baseline hsCRP	−.047	.78
Baseline HbA_{1c}	−.183	.28
Baseline LDL-C	−.061	.68
No. of diabetic medication	.222	.33
Smoking status[b]	.141	.52
Intervention[c]	.371	.032

[a] 0 = male; 1 = female.
[b] 0 = nonsmoker; 1 = current smoker.
[c] 0 = lifestyle modification intervention group; 1 = control group.

3.5. Blood pressure

After 6 months, a significant reduction was observed in both systolic and diastolic blood pressures in the intervention group. However, only the difference in changes of the systolic blood pressure was significant between the intervention and control group (P = .041; Table 2).

3.6. Carotid IMT

Participants in the intervention group showed no significant change in mean CCA IMT during the 6-month study period. The mean CCA IMT of the control group increased 0.083 ± 0.167 mm from baseline after 6 months (P = .029). The difference in changes of mean CCA IMT between the intervention and control groups was significant after adjusting for age, sex, baseline HbA_{1c}, number of diabetes medication, baseline hsCRP, baseline LDL-C, and smoking status (P = .032; Table 3). Pearson correlations were calculated for the change in mean CCA IMT to understand whether the larger changes in mean CCA IMT

Table 4
Correlations between change in mean carotid IMT and changes in other clinical parameters (adjusted by age and sex)

Parameters	Correlation coefficient	P
ΔFasting plasma glucose	0.31	.045
Δ2h PPG	0.37	.015
ΔHbA_{1c}	0.34	.028
ΔLDL-C	0.03	.87
ΔSystolic blood pressure	0.10	.53
ΔDiastolic blood pressure	0.11	.50
ΔBMI	0.02	.89
$\Delta HOMA_{IR}$	0.05	.77

Δ indicates change between baseline and after 6 months of each parameter.

were associated with changes in other metabolic or clinical parameters. The changes in HbA_{1c} (r = 0.34, P = .028), fasting plasma glucose (r = 0.31, P = .045), and in 2h PPG (r = .37, P = .015) correlated with the mean CCA IMT change after adjustment for age and sex (Table 4).

4. Discussion

Our results suggest that an intensive lifestyle modification intervention for 6 months in patients with type 2 diabetes mellitus can improve glycemic control, lower blood pressure, promote moderate weight loss, and attenuate the progression of carotid IMT. To our knowledge, this is the first study to evaluate the changes in carotid IMT in addition to other metabolic parameters in type 2 diabetic patients after a 6-month intensive lifestyle modification intervention. A lower HbA_{1c} is associated with a reduced risk of microvascular complications [24], and carotid IMT is commonly used as a surrogate marker for atherosclerotic diseases [6-10], although data on the relation of change in CIMT and risk of future events are limited at present [8]. Our results suggest that lifestyle modifications may have some beneficial effects on major diabetes complications that can influence the patient's morbidity and mortality.

Recent large-scale randomized controlled trials have shown that type 2 diabetes mellitus can be prevented or delayed by lifestyle modifications in individuals at high risk for the disease [25,26]. The effect of lifestyle modification in patients with established type 2 diabetes mellitus has also been studied in several trials involving a smaller study population [27-29]. Our intervention was carried out in an institutional setting, and was individualized and systematic. The intervention was based on a 16-lesson curriculum that focused on dietary modification, increased physical activity, and behavioral modification. Considering the frequency of person-to-person contact in the first 3 months, this intervention can be classified as a high-intensity trial [30]. In our study, the mean weight loss after 6 months for the intervention group was 2.8%, which is a little less than that achieved in other intensive interventions that most likely achieved a weight loss of 3% to 6% at 1-year follow-up in obese subjects. This should be because subjects who were not obese (BMI < 25 kg/m^2) were also included in the study (43%), and that the baseline weight was smaller in the patients who were obese compared with the subjects in other studies that were carried out in Western countries [25,26]. The mean weight loss in the obese subjects in the intervention group was 3.4%. The fact that many patients did not achieve the targeted daily energy intake may also play a part in the less than 5% weight loss in the obese subjects in the intervention group.

HbA_{1c} was decreased by 1% in the intervention group, whereas a 0.1% rise was seen in the control group after 6 months. Fasting plasma glucose and 2h PPG were significantly decreased in the intervention group. The UK Prospective Diabetes Study showed that each 1% reduction in mean HbA_{1c} was associated with a 21% reduction in risk for any end point related to diabetes, 21% for deaths related to diabetes, 14% for myocardial infarction, and 37% for microvascular complications [24]. The decrease in HbA_{1c} was similar to that seen in other interventional trials [27-29], and this degree of improvement has clinical significance.

There is a general agreement that exercise has an independent role in reducing blood glucose levels and improving insulin sensitivity in type 2 diabetic patients [31]. Changes in anthropometric parameters in the intervention group favor a beneficial effect on insulin sensitivity. However, $HOMA_{IR}$, which is an inexpensive and relatively simple method for assessing insulin resistance [19], showed no significant change in the intervention group. This may be due to the limitations of the validity of the $HOMA_{IR}$ in patients with lower BMI, lower beta-cell function, and higher fasting glucose levels [32]. The 6-month intervention lowered systolic blood pressure and had a small but nonsignificant beneficial effect on lipid profile. Hypertension and dyslipidemia are modifiable risk factors for cardiovascular mortality in patients with type 2 diabetes mellitus [33]. The intensive treatment of hypertension and lipid abnormalities in type 2 diabetes mellitus is known to significantly reduce the risk of macrovascular diseases [34,35]. These findings further suggest a possible beneficial effect of lifestyle modification on atherosclerosis in type 2 diabetic patients.

The carotid IMT was measured before and after the intervention to evaluate the effects of the lifestyle intervention on the progression of carotid atherosclerosis. Several studies have shown that increased carotid IMT confers risk of future coronary heart disease and stroke [8-10]. Lifestyle has a major influence on the development and progression of atherosclerosis. The Lifestyle Heart Trial and subsequent clinical trials showed that lifestyle modifications, including dietary changes, increased physical activity, smoking cessation, and weight control, can slow the progression of coronary atherosclerosis [4,5]. However, whether lifestyle changes can mediate a protective effect through a favorable influence on carotid atherosclerosis is still controversial [11-16]. Results from this study support the beneficial effects of lifestyle changes in attenuating the progression of carotid atherosclerosis. Although carotid IMT in the control group patients increased significantly, there was no significant change in carotid IMT in the intervention group. The interventional studies previously reporting no beneficial effect on carotid IMT after lifestyle modification were either studies of low intensity, which did not induce a significant weight loss, or one study of a shorter duration of 3 months [14-16]. If these interventions had been more intensive, a different result may have been seen.

Changes in mean CCA IMT correlated with changes in HbA_{1c}, fasting plasma glucose, and 2h PPG. Several epidemiologic studies have found an association of cardiovascular disease with glycemia in subjects with normal to diabetic glucose tolerance [36]. However, interventional studies have not yet demonstrated a convincing beneficial effect of glucose lowering on cardiovascular outcomes [37]. Regarding the effect of glycemic control on carotid IMT progression, Esposito et al [38] reported a regression of carotid IMT by reduction of postprandial hyperglycemia, and Yamasaki et al [39] reported a significant linear relationship of carotid IMT with HbA_{1c} levels and carotid IMT progression.

This study does have some limitations. First, the sample size was small, and the patients were recruited from an educational institution, not from private clinics. This may have resulted in the recruitment of more patients who had difficulty controlling hyperglycemia by conventional methods or a patient group with different characteristics from the general diabetes population, such as patients with a higher cardiovascular risk. Therefore, the findings presented here should be confirmed in a study involving a larger group of participants. Second, the intervention period was relatively short. Because the maintenance is critical to the success of lifestyle interventions, and diabetes is a lifelong problem, a study intervention involving a longer follow-up period is essential. Maximal weight loss is typically observed at 6 months in obesity trials, regardless of intervention mode. After the weight has been reduced, it takes a greater energy deficit and continuous physical activity to maintain the lower weight. Weight regain after 6 months has been observed in several studies, and this emphasizes the need for ongoing lifestyle coaching to support maintenance [30]. The ongoing Look AHEAD (Action for Health in Diabetes) trial that will evaluate the long-term effect (up to 11.5 years) of intensive lifestyle modification intervention on the prevention of cardiovascular disease in type 2 diabetes mellitus will provide us with more definite answers on the issue of cardiovascular disease in type 2 diabetes mellitus and lifestyle modification interventions [40]. The results of the present study may inform a positive outcome for this trial.

In conclusion, a 6-month lifestyle modification intervention in Korean type 2 diabetic patients resulted in improved glycemic control and decreased progression of carotid IMT. The CCA IMT progression showed positive correlation with change in HbA_{1c}, and fasting and 2-hour postprandial glucose.

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