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Research Article

Separate and Combined Effects of Resistance Training and Cucumber (*Cucumis sativus*) Juice Consumption on the Diabetic Indicators and Lipid Profile in Women with Type 2 Diabetes

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Abstract

Background: Type 2 diabetes is a metabolic disease with many consequences.
Objectives: This study aimed to evaluate the separate and combined effects of resistance training and cucumber (*Cucumis sativus*) juice consumption on diabetic indicators and lipid profiles in women with type 2 diabetes.
Methods: Women with type 2 diabetes (n = 40) were assessed in a randomized, double-blind study and categorized into four groups: (training + placebo), (training + supplement), supplement, and control. Blood sampling was performed 48 hours before and after the protocol, and blood indicators were evaluated to compare their changes among groups. One-way ANOVA statistical tests and Tukey's post hoc test were used to compare groups.
Results: The results indicated that separate resistance training significantly decreased fasting blood sugar (FBS), glycated hemoglobin (HbA1c), triglyceride (TG), total cholesterol (TC), and low-density lipoprotein (LDL), while high-density lipoprotein (HDL) significantly increased. Cucumber juice consumption significantly reduced FBS, HbA1c, TG, TC, and LDL, while HDL significantly increased ($P < 0.05$). Combined resistance training and consuming cucumber juice caused a more significant decrease in (FBS, HbA1c, TG, TC, and LDL), and HDL increased significantly ($P < 0.05$). Intergroup changes in (FBS, TG, TC, LDL) was significant ($P < 0.05$). Intergroup changes in (HbA1c and HDL) were significant ($P < 0.05$). However, differences in (HbA1c and HDL) between training and supplement groups were not significant ($P \geq 0.05$).
Conclusions: Separate and combined effects of resistance training and cucumber juice consumption improved diabetic indicators and lipid profile in women with type 2 diabetes.

Keywords: Type 2 Diabetes, Training, *Cucumis sativus*

1. Background

Diabetes mellitus is a chronic metabolic disorder with several physiological functional disorders with different causes. Type 2 diabetes is a type of diabetes characterized by a double deficiency as follows: Insufficient insulin is produced to meet the body's needs, leading to insulin secretion defects, or the insulin produced does not work well enough and causes insulin resistance (1). The occurrence of type 2 diabetes is mainly due to lifestyle and genetic factors. Studies have shown that a significant reduction in the incidence of type 2 diabetes can be achieved with a combination of maintaining a body mass index of 25 kg/m^2, eating more fiber and unsaturated fats, exercising, and avoiding smoking and alcohol (2). In recent years, sports activities and appropriate diets have been recommended as strategies to modify lifestyle for treating diabetes. Physical exercises in diabetic patients increase insulin sensitivity and decrease insulin resistance. Cauza et al. found that resistance training compared to endurance training caused a more significant decrease in fasting blood sugar and increased insulin sensitivity in people with type 2 diabetes (3). Researchers have suggested that people with diabetes do resistance training 2 - 3 days a week on non-consecutive days (4). Treating type 2 diabetes with synthetic drugs has relieved diabetic patients, but the high cost and their side effects have made it difficult for diabetic patients to access their benefits. Therefore, traditional medicine doctors have recommended several plants as complementary herbal medicines against diabetes, which are mostly cheap and without side effects (5). Cucumber (*Cucumis sativus*) is one of the plants that has attracted much attention, which belongs to the gourd family and is widely cultivated worldwide (6). Cucumber (*C. sativus*) contains flavonoids such as quercetin, apigenin, kaempferol, luteolin, lignans, triterpenes; vitamins like biotin, vitamin B1, vitamin K, and pantothenic acid, and minerals like copper, magnesium, potassium, manganese, and phosphorus, sterols, saponins and tannins (7). The cucumber is an essential plant with diverse medicinal activities, including antibacterial and antifungal activity (8), anti-acid and irritant activity (9), hepatoprotective activity (10), blood lipid-lowering activity, and many other activities. Therefore, cucumber plays a significant role in preventing and treating diseases (5). Other researchers have reported that cucumber is suitable for medicinal purposes against diseases such as diabetes mellitus, high blood pressure, gallstones, and constipation among traditional Asian medicines (6, 11). Based on reports, this edible plant has antihyperglycemic effects in some animal models (6). Diabetic patients should be evaluated for glycosylated hemoglobin levels in their blood. Glycosylated hemoglobin analysis in the blood provides evidence of a person's average blood sugar levels over the past two to three months. Glycosylated hemoglobin in the blood increases when the average plasma glucose increases (12). Epidemiological analyzes have shown that a 1% decrease in glycosylated hemoglobin is associated with a 14% decrease in the incidence of myocardial infarction, a 21% decrease in diabetes-related mortality, and a 37% decrease in microvascular outcomes (13). Therefore, glycated hemoglobin control at or below 7% is associated with a 76% reduction in long-term diabetes outcomes. As a metabolic disorder, diabetes is associated with increased levels of free radicals and decreased activity of antioxidants, and some studies have suggested that increased oxidative stress in diabetes may be due to increased formation of glycosylated hemoglobin. The increase in the formation of glycosylated hemoglobin develops diabetes and its consequences (14). Researchers have shown that regular exercise leads to a decrease in glycosylated hemoglobin levels (15). In addition, studies have shown that consuming cucumber extract, with its hypoglycemic effects, significantly reduces blood glycosylated hemoglobin (16). The studies in this field are limited, with many research gaps. Type 2 diabetes is one of the diseases associated with consequences such as dyslipidemia and atherosclerosis. Sports exercises improve lipid profile levels in people, which can be used as a non-pharmacological method in preventing and treating dyslipidemia and atherosclerosis, both consequences of diabetes. In addition, cucumber juice has attracted much attention as an herbal medicine in improving lipid profile levels. There are many research gaps in this field, warning the researchers to conduct such research.

2. Objectives

This research aims to determine whether performing resistance training and consuming cucumber (*C. sativus*) juice consumption can be effective in preventing the development of diabetes and improving the status of diabetic indicators and lipid profiles in women with type 2 diabetes.

3. Methods

3.1. Subjects

This study was approved by the ethics committee in biomedical research at Razi University, Kermanshah, Iran (ethical code: IR.RAZI.REC.1400.092). This experiment was conducted with a pretest-posttest design and random assignment of research groups (three experimental groups and one control group). Sedentary women aged 35 - 70 years (n = 40) with type 2 diabetes referred to the Kermanshah Research and Treatment Center of Diabetes were selected. All subjects were expressed about the experimental procedures and filled out written consent. Anthropometric characteristics were measured in the first session and divided into four groups: Training + placebo; training + supplement; and supplement and control groups.

3.2. Study Design

Critical confounding factors were controlled during the study, including diet, energy intake, possible supplements, and physical activity. The subjects completed food frequency questionnaires three days before and after the trial. There were no significant changes in food frequency before and after the intervention. During the intervention, subjects were asked to avoid high-fat and high-carbohydrate foods and take pharmaceutical supplements and steroid pills. Subjects also completed the physical activity questionnaire before the trial without a history of professional physical activity and walking and exercising two days a week. The subjects' physical activity was monitored during the research, and the subjects, except for the control group, were given an eight-week resistance training program (three sessions per week). Subjects from both training groups were asked to be at the resistance training site (eight weeks) at the designated time. Subjects in the (training + supplement), supplement (training + placebo), and control groups consumed 240 mL of supplement (cucumber juice) or placebo (solution containing water + cucumber food coloring) for eight weeks. Then, blood indicators (diabetic and lipid indicators) were evaluated to compare their changes from pre-test to post-test among groups 48 hours before and after the protocol.

3.3. Resistance Training Program

The research protocol was implemented in the gymnasium of the Faculty of Physical Education of Razi University. Subjects were taught to perform sports movements before implementing the research protocol. Subjects were tested for 1 RM to determine muscle strength. The resistance training program with a ten-minute warm-up began and ended with a ten-minute cool-down (stretching and relaxation). The main body of the resistance training program consists of 40-minute sessions performed three times a week (odd days) for eight weeks. Different training movements were included: Chest press, rowing movement with cable, shoulder press, cable lat, abdominal crunch, leg press, front leg, back arm with line, and forearm with cable. Each training movement consisted of eight-ten repetitions with two sets. The rest period between training rounds was 2 min. The resistance training intensity will be 60% of 1 RM for the first two weeks of implementing the protocol (17). One RM movements were measured again in the second, fourth, and sixth weeks to comply with the overload and gradual progress principle (18) (Table 1).

Table 1. Resistance Training Schedule

Week	Intensity (%1 RM)	Exercise Duration (Minutes)
1	60	40
2	60	40
3	65	40
4	65	40
5	70	40
6	70	40
7	75	40
8	75	40

3.4. Supplementation Protocol

The research design was experimental and double-blind. Subjects consumed a dose of cucumber (*C. sativus*) beverage (240 mL) in the training + supplement and supplement groups. Training + placebo and control groups consumed an equal amount of placebo (240 mL) that contained water + cucumber food coloring for eight weeks (24 sessions). The placebo was prepared to be similar in color and taste to cucumber (*C. sativus* L.) juice. Subjects did not know what they received (cucumber juice or placebo). In addition, the researcher did not know about this process. The research assistant gave the subjects a cucumber (*C. sativus*), beverages, and a placebo in a double-blind manner. The research assistant ensured that the entire volume determined (240 mL) for each person was consumed.

3.5. Laboratory Assessments

Blood samples (7 mL) were collected from participants before and after the trial and placed in a centrifuge with 3000 rpm for 15 min to separate their plasma. Then, diabetic indicators (fasting blood sugar (FBS), glycated hemoglobin (HbA1c)) and lipid profile (total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL)) were measured in pre-test and post-test in the four groups (Figure 1).

3.6. Statistical Analysis

The data were analyzed using SPSS software version 22, and the results were expressed as mean ± SD. The difference values between the pre-test and the post-test were calculated and reported as delta. The analysis of variance (one-way ANOVA) was utilized, and Tukey's post hoc test was used for pairwise comparison between groups. A significant level was considered at $P \leq 0.05$.

4. Results

Table 2 shows anthropometric characteristics.

The diabetic indicators (FBS, HbA1c) and lipid profile (TC, TG, LDL) showed a significant decrease from the pre-test stage to the post-test stage ($P < 0.05$), while HDL increased significantly in all three groups (training + placebo, training + supplement and supplement) from the pre-test stage to the post-test stage after intervention ($P < 0.05$). No significant changes were observed in all the control group variables from the pre-test to the post-test ($P \geq 0.05$). The delta of the data was investigated using a one-way ANOVA statistical test (Table 3).

The one-way ANOVA statistical test results showed a significant difference between the delta data in the intervention groups (FBS, HbA1c, TG, TC, HDL, and LDL) ($P = 0.0001$). Tukey's post hoc test was used

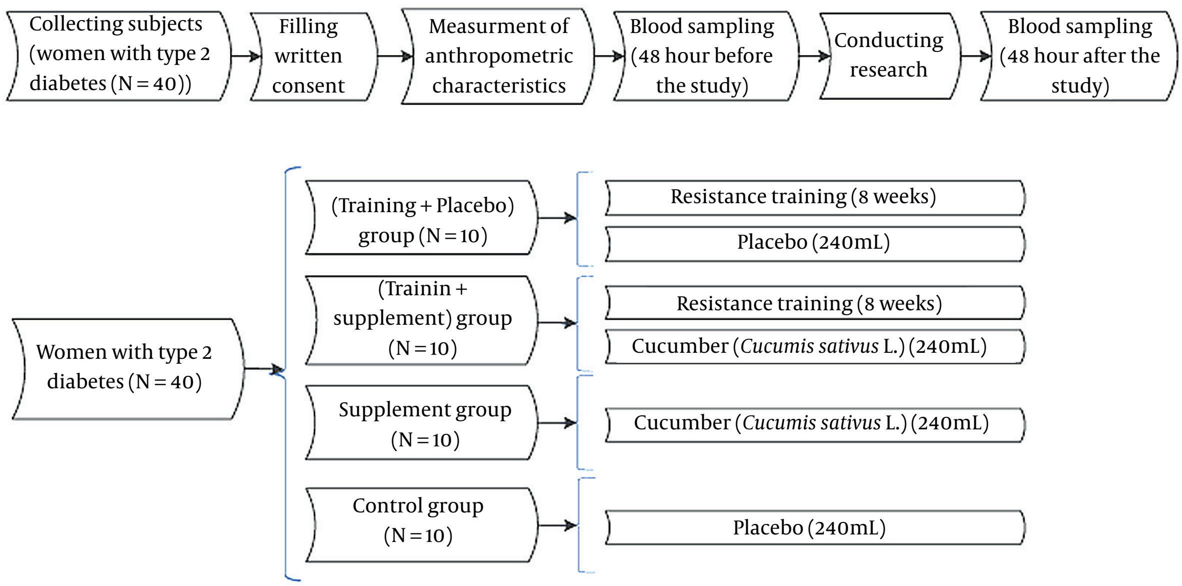

Figure 1. Schematic diagram of research implementation steps

Table 2. Anthropometric Measurements (Weight, Height, BMI) [a]

Groups	Age (y)	Weight (kg)	Height (m)	BMI (kg/m²)
T + P	49.30 ± 4.64	76 ± 12.82	1.58 ± 0.04	30.50 ± 5.66
T + S	48.90 ± 4.30	77.08 ± 9.94	1.56 ± 0.04	31.69 ± 3.76
Spl	49.50 ± 4.30	80.12 ± 10.48	1.55 ± 0.04	33.23 ± 5.73
Ctl	49.40 ± 4.35	82.67 ± 10.53	1.57 ± 0.04	33.35 ± 4.86

Abbreviations: T + P, training + placebo; T + S, training + supplement; Spl, supplement, Ctl, control.
[a] Values are expressed as mean ± SD.

Table 3. Overall Scores of the Diabetic Indicators and Lipid Profile at Baseline and After Eight Weeks of Intervention (Mean ± SD)

Variables	T + P		T + S		Spl		Ctl	
	Before	After	Before	After	Before	After	Before	After
FBS (mg/dL)	140.20 ± 14.14	119 ± 14.16	280.10 ± 65.85	243.60 ± 66.14	154.40 ± 18.56	135.40 ± 18.23	145.10 ± 12.85	145.10 ± 12.74
HbA1c (%)	6.75 ± 0.80	6.19 ± 0.76	9.76 ± 1.60	7.61 ± 1.38	9.97 ± 2.09	9.29 ± 1.91	6.91 ± 0.42	6.93 ± 0.42
TC (mg/dL)	196.90 ± 36.66	181.80 ± 42.16	249 ± 17.83	170.40 ± 9.46	195.20 ± 24.47	160.80 ± 31.42	170.30 ± 14.55	170.50 ± 14.44
TG (mg/dL)	174.30 ± 23.61	154.40 ± 24.83	264.90 ± 51.87	180.80 ± 48.48	202.80 ± 22.92	139.80 ± 22.83	163 ± 18.39	163.10 ± 18.35
HDL (mg/dL)	29.90 ± 10.27	39.50 ± 7.23	29 ± 6.28	52.60 ± 4.71	27.40 ± 7.87	40.90 ± 8.19	29.30 ± 6	29.20 ± 5.65
LDL (mg/dL)	90.40 ± 14.44	82.70 ± 14.36	132.70 ± 28.51	106.70 ± 28.51	117.90 ± 11.99	104.20 ± 11.98	109 ± 10.63	109.20 ± 10.51

Abbreviations: FBS, fasting blood sugar; HbA1c, glycated hemoglobin; TG, triglyceride; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; T + P, training + placebo; T + S, training + supplement; Spl, supplement; Ctl, control.

considering a significant difference between the delta of the intervention groups and for pairwise comparisons.

According to Tukey's post hoc test on FBS, TG, TC, and LDL, there is a significant difference between the delta data in (FBS, TG, TC, and LDL) between the training (training + supplement), supplement groups with the control group ($P < 0.05$). There was a significant difference between the delta data in (FBS, TG, TC, and LDL) between training and (training + supplement) ($P < 0.05$). There was a significant difference between the delta data in FBS, TG, TC, and LDL between (training + supplement) and supplement groups ($P < 0.05$). There is a significant difference between the delta data in (FBS, TG, TC, and LDL) between training and supplement groups ($P < 0.05$).

There was a significant difference between the delta data in HbA1c and HDL between the training (training + supplement) and supplement groups with the control group regarding HbA1c, HDL ($P < 0.05$). There was a significant difference between training and (training + supplement) ($P < 0.05$). HbA1c and HDL showed a significant difference between (training + supplement) and supplement groups ($P < 0.05$). There was no significant difference between the delta data in HbA1c and HDL between training and supplement groups ($P \geq 0.05$).

5. Discussion

Several drugs for the treatment of type 2 diabetes disease, which are effective in treating type 2 diabetes but have side effects. Therefore, discovering natural ways without side effects in type 2 diabetic patients to manage and treat type 2 diabetes is interesting. No research has investigated the effect of separate and combined effects of resistance training and cucumber (*C. sativus*) juice consumption on diabetic indicators and lipid profile of sedentary women with type 2 diabetes. This is the first study that evaluated the effect of separate and combined effects of resistance training and cucumber (*C. sativus*) juice consumption on diabetic indicators and lipid profiles of women with type 2 diabetes. The results showed that carrying out resistance training for eight weeks significantly reduced diabetic indicators (FBS, HbA1c) and lipid profile (TC, TG, LDL), but HDL increased significantly after eight weeks of resistance training in women with type 2 diabetes. Cucumber juice consumption for eight weeks significantly reduced diabetic indicators (FBS, HbA1c) and lipid profile (TC, TG, LDL), but HDL significantly increased after eight weeks of Cucumber juice consumption. Both training and supplement groups led to a reduction in HbA1c. However, changes in HbA1c between the training and supplement groups were insignificant ($P \geq 0.05$). Combined resistance training and cucumber (*C. sativus*) juice consumption led to a more significant reduction in diabetic indicators (FBS, HbA1c) and lipid profile (TC, TG, LDL) for eight weeks. Nevertheless, HDL increased after intervention ($P < 0.05$). The results of this research were consistent with those of Cauza et al. (3). This study investigated the effects of four months of resistance training versus aerobic endurance training on metabolic control, muscle strength, and cardiovascular endurance in patients with type 2 diabetes. The research showed that resistance training caused a significant decrease in glycosylated hemoglobin, blood glucose, insulin resistance, cholesterol, triglycerides, and LDL, while HDL significantly increased. These changes were not observed in the group that did aerobic endurance training. In this study, resistance training is important in treating type 2 diabetic patients (3). Fathi et al. showed that eight weeks of resistance training improved related indicators in middle-aged women with type 2 diabetes (19). Resistance training significantly reduced (FBS and HbA1c) in type 2 diabetic women (19). These results were consistent with those of the current research. Moreover, the effect of resistance training on reducing fasting blood sugar and glycosylated hemoglobin was consistent with the results of these studies (20, 21). Studies have shown that the effect of endurance and resistance activity on the reduction of glycosylated hemoglobin is almost the same. However, resistance training is more effective than endurance training in reducing fasting blood sugar. Resistance training has better results in diabetic patients (22). Probably, physical activity improves the body's sensitivity to insulin through the effect on isoform-4 of glucose transporters in skeletal muscles, insulin receptor substrates, and increasing muscle mass (23). Resistance training in patients with type 1 diabetes improves muscle strength, lipid profile, and better control of blood glucose levels. In contrast, resistance training in patients with type 2 diabetes leads to improved blood pressure and increased muscle mass and strength, which may positively affect insulin responsiveness and metabolic control (4). The results of this research were consistent with that of Bartimaeus et al. (5). This study examined the effects of acute consumption of 200 and 400 mL cucumber (*C. sativus*) juice on blood glucose concentration in healthy subjects aged 18 - 29. The results of their research showed that the consumption of cucumber (*C. sativus*) juice has effects that counteract the increase in blood sugar, and these effects appeared when people consumed a large amount of cucumber juice (400 mL) (5). The antidiabetic activity of cucumber may be due to the hypoglycemic saponins, tannins, triterpines, alkaloids, and flavonoids (24). Cucumber's antidiabetic activity and lowering of blood sugar have been attributed to kaempferol. Kaempferol is a dietary flavonoid in fruits, vegetables, beverages, chocolate, and herbs. Kaempferol has anti-inflammatory, anti-cancer, and anti-diabetic properties, which protect the liver and prevent metabolic diseases. Kaempferol has been reported to lower blood sugar and inhibit alpha-amylase and alpha-glucosidase (two carbohydrate-hydrolyzing enzymes found in the digestive tract) (25). Ibitoye et al. showed that kaempferol isolated from cucumber inhibits alpha-amylase and alpha-glucosidase enzymes with anti-diabetic properties and hypoglycemic and antioxidant activities (26). The present study's results were aligned with those of Tamuno-Emine et al., who showed that cucumber juice consumption improved diabetic condition by increasing insulin levels and lowering glucose levels for 35 days in diabetic male Sprague Dawley rats (27). This study also indicated that high-dose cucumber juices have better hypoglycemic ability since they have higher amounts of flavonoids, alkaloids and lower carbohydrate content (27). Removing damage factors can drive B-cells to undergo redifferentiation and restore their function (28). In addition, the cucurbitacin content of Cucumber helps regulate insulin release (29), which can stimulate insulin release from remnant pancreatic B-cells (30). Molly et al. evaluated the effects of consuming 100 - 125 g of cucumber slices for 45 consecutive days in menopausal healthy women aged 45 - 65 with mild hyperlipidemia (7). The results showed that cucumber significantly reduced cholesterol, triglyceride, and LDL levels in menopausal women and improved their lipid profiles. The results were consistent with those of the present study (7). Ezeodili et al. investigated the effects of cucumber (*C. sativus*) on the lipid profile in apparently healthy undergraduate students. Based on this study consuming 400 g of cucumber for 21 days in a fasting state significantly decreased cholesterol, triglycerides, and HDL (31). Compared to the pre-test state, LDL did not change significantly. The fact that cucumber consumption decreases cholesterol and triglycerides was in line with the current research results, but the fact that HDL has decreased and LDL has not changed significantly compared to the pre-test state is not in line with the results of the present research (31). Soltani et al., in a randomized, double-blind, placebo-controlled clinical trial, explored the effects of cucumber seed extract consumption on the serum lipid levels in adult patients with mild hyperlipidemia (32). This research showed that cucumber seed extract significantly reduced cholesterol, triglyceride, and LDL levels and significantly increased HDL levels. Cucumber seed extract significantly improved serum lipid levels in adult hyperlipidemic patients (32). The results were consistent with those of the current research. Phytosterols in cucumber lead to lowering cholesterol and LDL-C by inhibiting cholesterol absorption from the small intestine (7). The phytosterols in cucumbers significantly lower cholesterol. In addition, cucumber contains saponin, which has cholesterol-lowering effects and is used at least as an adjuvant in managing patients with cardiovascular diseases (31). Combining eight weeks of resistance training and consuming cucumber (*C. sativus*) juice consumption led to more significant improvements in diabetic and lipid indicators than carrying out resistance exercises or consuming cucumber (*C. sativus*) juice separately.

5.1. Conclusions

The results showed a considerable improvement in diabetic indicators and lipid profile after eight weeks of separate and combined resistance training and cucumber (*C. sativus*) juice consumption in women with type 2 diabetes. Separate and combined resistance training and cucumber (*C. sativus*) juice consumption benefit the well-being of sedentary adult women with type 2 diabetes. The resistance training should be in the weekly exercise program of women with type 2 diabetes. Cucumber juice beverages should be set as part of the daily diet in women with type 2 diabetes. Combined resistance training and cucumber (*C. sativus*) juice consumption had more beneficial effects on the diabetic indicators and lipid profile as two ways to treat and manage type 2 diabetes. Finally, further studies are needed to explore the mechanisms of improving diabetic indicators and lipid profiles in type 2 diabetic patients of both sexes.

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Footnotes

Authors' Contribution: Maryam Lotfi developed the original idea and the protocol, abstracted and analyzed data, wrote the manuscript, and is a guarantor. Maryam Lotfi, Nasser Behpoor, Merali Rahimi and Afshar Jafari contributed to the development of the protocol, abstracted data, and prepared the manuscript.

Conflict of Interests: The authors declare no conflicts to disclose.

Ethical Approval: This study was approved by the Ethics Committee in Biomedical Research at Razi University, Kermanshah, Iran (code: IR.RAZI.REC.1400.092).

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Informed Consent: Written consent was obtained from the subjects after being informed about the purpose and protocol of the study.

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