

Two Cases of Successful Type 2 Diabetes Control with Lifestyle Modification in Children and Adolescents

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Obesity and obesity-related disease are becoming serious global issues. The incidence of obesity and type 2 diabetes has increased in children and adolescents. Type 2 diabetes is a chronic disease that is difficult to treat, and the accurate assessment of obesity in type 2 diabetes is becoming increasingly important. Obesity is the excessive accumulation of fat that causes insulin resistance, and body composition analyses can help physicians evaluate fat levels. Although previous studies have shown the achievement of complete remission of type 2 diabetes after focused improvement in lifestyle habits, there are few cases of complete remission of type 2 diabetes. Here we report on obese patients with type 2 diabetes who were able to achieve considerable fat loss and partial or complete remission of diabetes through lifestyle changes. This case report emphasizes once again that focused lifestyle intervention effectively treats childhood diabetes.

Key words: Children, Adolescents, Obesity, Type 2 diabetes, Lifestyle modification, Remission

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INTRODUCTION

Obesity and obesity-related diseases are serious public health issues worldwide, and the increased incidence of type 2 diabetes in children and adolescents is associated with the increased incidence of obesity.^{1,2} Excess weight gain is a risk factor for both type 2 diabetes and insulin resistance. Obesity refers to excessive fat accumulation and may affect the clinical course of diabetes in terms of insulin resistance. Therefore, the accurate assessment of obesity is important.³ Body mass index (BMI) is used as an indicator to evaluate weight excess or obesity.⁴ However, BMI is limited in that it is the sum of fat-free mass index (FFMI) and fat mass index (FMI) and does not only reflect excess fat.^{5,6} Therefore, it may be helpful to use body composition analysis that measures fat mass (FM) without fat-free mass (FFM) as a tool to evaluate obesity. Although type 2 diabetes is considered a chronic disease that is difficult to

completely cure^{7,8}, studies have reported complete remission of type 2 diabetes in adults after intensive lifestyle modification.⁹ Here we report two cases of type 2 diabetes with partial or complete response to lifestyle modification, particularly FM decrease. Our findings emphasize that lifestyle modifications including dietary treatment and exercise therapy comprise the first-line treatment in obese patients with type 2 diabetes.¹⁰

CASE REPORT

Case 1

Patient ID: Ms. L, 17 years and 5 months, female

Complaints: Polydipsia, polyuria

Family history: Mother with hypertension, father with heart failure.

Past medical/social history: No significant history

Table 1. Anthropometric data and patient body composition profiles of adolescent girls with type 2 diabetes who achieved remission after stopping medications

	Case1		Case2	
	Baseline	Follow up	Baseline	Follow up
Age (year)	17.5	21.5	12.1	14.9
Height (cm)	173.1	174	158.9	160.8
Weight (kg)	107.2	80.2	75.5	59.9
BMI (kg/m ²)	35.8	27.1	29.9	23.2
Height Z score	2.38	2.13	1.01	0.43
Weight Z score	3.66	2.5	2.72	0.98
BMI Z score	3.28	1.87	2.62	0.99
FFM (kg)	53.2	49.6	43.4	41.8
FM (kg)	54.0	30.6	32.1	18.1
FFMI (kg/m ²)	17.8	16.8	17.2	16.2
FMI (kg/m ²)	18.0	10.3	12.7	7.0
FFMIZ	2.06	1.56	2.10	1.51
FMIZ	2.87	1.47	2.51	0.32
PBF (%)	50.4	38.2	42.5	30.2

BMI, body mass index; FFM, fat free mass; FM, fat mass; FFMI, fat free mass index; FMI, fat mass index; FFMIZ, fat free mass index Z score; FMIZ, fat mass index Z score; PBF, percent body fat.

History of present illness: This 17-year-old girl was diagnosed with diabetes at another hospital after a 1-month history of persistent polydipsia and polyuria. She presented to Konkuk University Medical Center for further diagnosis and treatment of her persistent symptoms.

Physical examination: On admission, her height was 173.1 cm (>97th percentile), weight was 107.2 kg (>97th percentile), and BMI was 35.8 kg/m² (>97th percentile) (Table 1). She appeared obese but did not look ill and her mental status was intact. Her vital signs were normal except for a blood pressure of 137/81 mmHg (95–99th percentile). Her skin was warm and no dry mucous membranes were observed. A chest examination was unremarkable. No enlargement of the liver or spleen was appreciated on an abdominal examination. The rest of the physical exam was unremarkable.

Lab findings: Labs on admission revealed a glycated hemoglobin (HbA1c) of 11.1%, fasting plasma glucose level of 102 mg/dL, insulin level of 23.12 μ IU/mL, and C-peptide level of 4.13 ng/mL. Liver function tests revealed an elevated serum aspartate transaminase (AST) level of 115 IU/L and serum alanine transaminase (ALT) level of 141 IU/L. A lipid panel demonstrated a total cholesterol level of 133 mg/dL, triglycerides of 71 mg/dL, and high-den-

Table 2. Biochemical profiles of adolescent girls with type 2 diabetes who achieved remission after stopping medications

	Case1		Case2	
	Baseline	Follow up	Baseline	Follow up
Age (year)	17.5	21.5	12.1	14.9
HbA1c (%)	11.1	4.9	9.9	6.0
C-peptide (ng/mL)	4.13	2.13	2.97	2.79
Insulin (μ IU/mL)	23.12	15.69	15.85	5.62
Glucose (mg/dL)	102	84	202	97
Total cholesterol (mg/dL)	133	114	165	115
Triglyceride (mg/dL)	71	59	104	70
HDL cholesterol (mg/dL)	49	51	50	30
AST (IU/L)	115	20	47	20
ALT (IU/L)	141	12	69	34

HbA1c, glycated hemoglobin A1c; HDL, high lipoprotein; AST, aspartate transaminase; ALT, alanine transaminase.

sity lipoprotein cholesterol (HDL-C) of 49 mg/dL (Table 2). The total protein and albumin level was 7.0 g/dL and that of albumin was 4.5 g/dL. The free fatty acid level was elevated at 1214 μ Eq/L.

Radiologic findings: There were no abnormal findings on a chest radiograph. An abdominal ultrasound showed severe fatty infiltration of the liver.

Treatment and progress: For glycemic control, the patient was started on oral medications (metformin 500 mg BID, glimepiride 1 mg QD) as well as a diet and exercise program as a lifestyle modification. Her dietary and nutritional knowledge were evaluated, and she was counseled to have regular meals with 70–75 g of proteins per day and maintain daily nutritional requirements of approximately 1,800 kcal. She was recommended to consume a low-carb, low-fat diet, limit high saturated fats, track her intake, and attend outpatient appointments every 1–2 months. She was instructed to perform aerobic and weight exercises that improve muscle strength for more than 1 hour at least 3 times per week. For 1 year, she did aerobic and anaerobic exercises for an hour or more per day. After 1 year, she incorporated a 7 km walk daily and Pilates more than 3 times per week to her exercise program. In the outpatient setting, we assessed her adherence to therapy at 1–2 month intervals, offered motivational support, and advised her to gradually increase her exercise duration rather than intensity. We measured her height and weight every year and used InBody720, a type of bioelectrical impedance analysis (BIA), to accurately evaluate her obesity. On diagnosis, the patient's BMI was 35.8 kg/m² (FMI, 18.0 kg/m²;

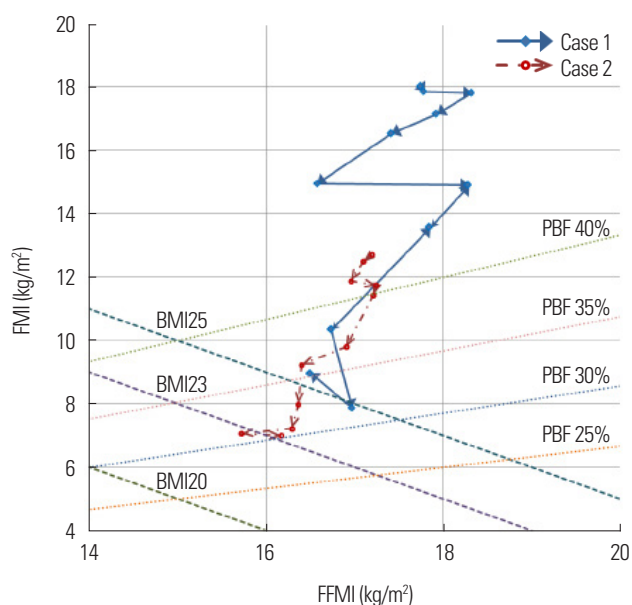


Figure 1. Plot of changes in FFMI and FMI in two adolescent girls with T2DM who achieved remission. T2DM, type 2 diabetes; BMI, body mass index; PBF, percent body fat; FFMI, fat free mass index; FMI, fat mass index.

FFMI, 17.8 kg/m²), scoring >97th percentile, and percent body fat (PBF) was 50.4%. During the 2 years of outpatient monitoring, she had no difficulty controlling her blood sugar level using the combination of oral medication and lifestyle modification. However, the dose of metformin was increased to 1,000 mg BID due to difficulty maintaining her HbA1c < 7.0% on the previous regimen; at that time, she was still considered obese with a BMI of 35.1 kg/m² (FMI, 17.2 kg/m²; FFMI, 17.9 kg/m²) and PBF of 48.9%. Her weight and body composition during treatment are shown in Fig. 1.

Three years later, the patient's dietary therapy and exercise program resulted in an increased FFMI at 18.3 kg/m² and reduced FMI at 14.9 kg/m², leading to discontinuation of the glimepiride and a reduction in the metformin dose to 500 mg BID.

Four years later, her HbA1c decreased to 5.4% and the metformin was discontinued due to her successful glycemic control. At that time, her fasting blood glucose level was 97 mg/dL, insulin level was 5.62 µIU/mL, and C-peptide level was 2.13 ng/mL. Her BMI was 27.1 kg/m² (FMI, 10.3 kg/m²; FFMI, 16.8 kg/m²) and PBF was 38.2%, which is still considered obese based on the World Health Organization diagnostic criteria for Asian adults; however, it was 8.7 kg/m² less than her BMI prior to treatment and her FMI had decreased by 7.7 kg/m². Her FFMI was also reduced by 1.0

kg/m², but still belonged to the 90–95th percentile; thus, her nutritional status was not a concern (Table 1). Liver function tests and a lipid panel revealed AST 20 IU/L, ALT 12 IU/L, total cholesterol 114 mg/dL, triglycerides 59 mg/dL, and HDL-C 51 mg/dL (Table 2). Her HbA1c has remained at < 5.7% for more than a year without oral medications and will continue to be followed.

Case 2

Patient ID: Ms. A, 12 years and 10 months, female

Complaints: Hyperglycemia

Family history: Father with type 2 diabetes under treatment

Past medical/social history: No significant history

History of present illness: 12-year-old female who presented to Konkuk University Medical Center with post-prandial hyperglycemia of 330 mg/dL measured by her father one day prior to admission. Menarche occurred 1 year prior and her menstrual cycles were regular.

Physical examination: On admission, the patient's height was 158.9 cm (25–50th percentile), weight was 75.5 kg (>97th percentile), and BMI was 29.9 kg/m² (>97th percentile) (Table 1). Her vital signs were within the normal range with a blood pressure of 112/68 mmHg, pulse of 72 beats/min, respiratory rate of 20 breaths/min, and temperature of 36.6°C. She had a clear mental status, warm skin, and moist mucous membranes. A chest examination revealed no specific findings, while an abdominal examination revealed no hepatomegaly or splenomegaly. The rest of the physical examination was unremarkable.

Laboratory findings: Laboratory tests at the time of admission revealed an HbA1c level of 9.9%, fasting blood glucose level of 202 mg/dL, insulin level of 15.85 µIU/mL, and C-peptide level of 2.97 ng/mL. Liver function tests showed an elevated AST level at 47 IU/L and ALT level at 69 IU/L. A lipid panel and comprehensive metabolic panel showed a total cholesterol level of 165 mg/dL, triglyceride level of 104 mg/dL, HDL-C of 50 mg/dL, total protein of 7.6 g/dL, and albumin of 4.8 g/dL (Table 2). The free fatty acid level was elevated at 671 µEq/L.

Radiologic finding: There were no significant findings on a chest radiograph. An abdominal ultrasound showed moderate fatty liver.

Treatment and progress: For glycemic control, combination

therapy of oral medication (metformin 500 mg BID) and lifestyle modification through adjustments in dietary habits was prescribed. We evaluated her dietary and nutritional knowledge and then counseled her to consume regular meals with 70–90 g of protein per day, maintain daily nutritional requirements of approximately 1800 kcal, and eat a low-carb, low-fat diet. She was recommended to modify her habitual preference of salty and spicy foods, reduce her salt intake, track her meals, and attend outpatient monitoring appointments every 1–2 months.

For an exercise program, she was instructed to include aerobic and weight exercises that improve muscle strength. She was advised to walk > 1 hour at least 5 days per week and visit a health training center for ≥ 1 hour of strength exercises at least 3 times per week. We measured her height and weight every 2 months, and used InBody720, a type of BIA for accurate assessment of obesity. On diagnosis, patient's BMI was 29.9 kg/m^2 (FMI, 12.7 kg/m^2 ; FFMI, 17.2 kg/m^2) and PBF was 42.5%. Two years later after the diagnosis, an abdominal ultrasound showed improvements in her fatty liver and her HbA1c was successfully reduced to 6.0%. The oral medication was discontinued due to the successful glycemic control. At the time, her fasting blood sugar was 97 mg/dL, insulin level was $5.62 \text{ } \mu\text{IU/mL}$, and C-peptide level was 2.79 ng/mL . Her BMI (FMI + FFMI) was 23.2 kg/m^2 ($7.0 \text{ kg/m}^2 + 16.2 \text{ kg/m}^2$), which was within the overweight range (85–90th percentile), and her PBF was 30.2%. Her BMI at that point was 6.7 kg/m^2 lower than that prior to therapy, with a 5.7 kg/m^2 reduction observed in her FMI (Table 1). Liver function tests and a lipid panel revealed the following: AST, 20 IU/L; ALT, 34 IU/L; total cholesterol, 115 mg/dL; triglycerides, 70 mg/dL; and HDL-C, 30 mg/dL (Table 2). The changes in the patient's weight and body composition during treatment are shown in Fig. 1. Since discontinuing the oral medication, the patient has maintained an HbA1c level < 6.5%.

DISCUSSION

The prevalence of type 2 diabetes is increasing with changes in dietary habits and increases in the incidence of obesity among children and adolescents. Although it is already known that a reduced caloric intake and weight loss through lifestyle modifications can treat diabetes, few cases demonstrating such an effect have been re-

ported to date.⁹ As discussed previously in two cases, a notable reduction in FM resulted in an HbA1c level < 6.5% and improved glycemic control as well as successful maintenance of HbA1c at goal level without medications. According to the 2009 consensus statement reported by the American Diabetes Association, a complete response is defined as blood sugar in the normal range for > 1 year without any medications (fasting blood sugar < 100 mg/dL, HbA1c < 5.7%). Partial response is defined as a blood sugar level below the diabetes range for > 1 year without any medications or medical procedures (HbA1C < 6.5%; fasting blood sugar, 100–125 mg/dL).¹¹ In the two cases presented above, significant decreases in BMI and PBF were observed as well as subsequent improvements in HbA1c and fasting blood sugar level. In developing children, weight gain occurs with increasing age, and increases in BMI are common. However, such increases in BMI are due to increases in FFM, not FM.⁶ Appropriate growth is one of the important objectives of pediatric diabetes management and treatment. Since proper nutrition and hormonal balance are essential for growth, it is more important to achieve a reduction in FM than a reduction in weight by having regular meals that are low in carbs and fat with a normal protein intake.

Weight loss through lifestyle modification generally affects FFM. In the cases discussed above, both patients had elevated FM and FFM on admission. By balancing appropriate dietary changes with aerobic and anaerobic exercises, the patient was able to maintain FFM and incur no significant effect on growth. In the present case, the patient was instructed to spend 1 hour exercising at least 3 times per week, assessed for compliance as an outpatient every 1–2 months, offered continuous motivational support, and told to gradually increase her exercise duration.

A recent study reported that oral medication was eventually needed to control hyperglycemia in patients with diabetes refractory to management with proper lifestyle modification.¹² However, lifestyle modification is important, and is a cornerstone in the treatment of diabetes, and it should be a mandatory treatment for type 2 diabetes. In females, it is common to see an increase in PBF with progression of puberty.^{13,14} However, here we report cases of complete remission of diabetes in teenage girls with lifestyle modification and emphasize once again that intensive lifestyle improvement is an effective early treatment for diabetes.¹⁵

Our results demonstrate that intensive lifestyle modification in-

cluding regular exercise and dietary changes is very effective in the treatment of obese patients with type 2 diabetes.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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