Diet and physical activity interventions do have effects on body composition and metabolic syndrome parameters in overweight and obese adolescents and their mothers

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To determine the effects of lifestyle intervention and diet on body composition, anthropometric measurements, and metabolic syndrome (MS) in obese and overweight adolescents and their mothers, a diet and lifestyle intervention program was administered for 16 weeks to 19 9-17-year-old (12.52±2.85 years) adolescents (female/male, 8/11) with a body mass index (BMI) value over the 90th percentile; hemoglobin (Hb)A1C, fasting insulin, homeostasis model assessment of insulin resistance (HOMA-IR), fibrinogen, and C-reactive protein levels of the adolescents and anthropometric measurements of the mothers were compared. In some of the anthropometric values (body weight (BW), BMI, waist circumference (WC), skinfold thicknesses, body fat tissue, and lean tissue mass), a statistically significant difference was observed in pre- and post-application measurements ($p<0.05$). There was a significant difference in pre- and post-application values of systolic and diastolic blood pressure and some biochemical parameters (uric acid, total cholesterol, high density lipoprotein, low density lipoprotein, triglyceride, and HOMA-IR) ($p<0.05$); however, there was no significant difference in pre- and post-application values of fasting blood glucose, aspartate transaminase, alanine transaminase, albumin, HbA1C, fasting insulin, and fibrinogen ($p>0.05$). MS was observed in 52.6% of the participants at baseline, and this rate was found as 15.8% based on the measurements carried out at week 16, which is a statistically significant decrease ($p<0.05$). There was a statistically significant difference in pre- and post-study values of BW, BMI, body fat mass, basal metabolic rate, WC, hip circumference, hip/waist, and skinfold thickness in mothers. A 16-week diet and lifestyle intervention program for overweight and obese adolescents involving their mothers resulted in significant improvement in obesity and MS treatment.

***Key words:** adolescents, obesity, diet, physical activity, metabolic syndrome.*

Obesity is an independent and important risk factor for cardiovascular diseases, hypertension, diabetes, and psychosocial problems. With an increasing degree and duration of obesity, these complications occur earlier and more frequently. If obesity is accompanied by hypertension, dyslipidemia, insulin resistance, and metabolic syndrome (MS), the risk of cardiovascular diseases increases even more[1].

In many countries, childhood obesity has been dramatically increasing since the 1990s. About 1% of children in developed countries are becoming overweight each year, and about 10% of school-age children worldwide are reported to be overweight[2]. Although MS is defined in adult ages, it has also been encountered recently as a common problem among children and adolescents[3]. The abnormalities defined in MS in children are increased serum glucose and triglyceride levels, increased blood pressure, increased waist circumference, and low high-density lipoprotein- cholesterol level[4]. Increasing obesity among children and adolescents is the leading factor that increases the MS rate among these age groups[3].

The primary purposes of obesity treatment in children and adolescents are to provide an adequate and balanced nutrition, to analyze their eating misbehaviors and replace them with good behaviors, and to help them acquire a healthy lifestyle. A sedentary lifestyle is another leading factor to be overcome in the treatment of obesity[5]. Lifestyle behaviors, such as healthy nutritional habits, are developed or re-shaped during the adolescence period. These behaviors are generally influenced by several agents, such as family, peers and the media[6]. Lifestyle modifications, including dietary changes and improvements in physical activity, are the mainstay of treatment in children with obesity and MS[7]. Therefore, first, the families of obese children and adolescents with limited knowledge regarding health and diet-related issues[8] should be informed via the training programs.

This study was performed to determine the effects of diet and physical activity modifications on body composition and MS components in overweight and obese adolescents and their mothers.

Material and Methods

Subjects

The study included 19 adolescents (9-17 years old; 8 girls, 11 boys) with a body mass index (BMI) value >90th percentile and who had at least one or more components of MS. The mean age of the adolescents participating in this study was 12.52±2.85 years. The percentages of overweight (BMI percentile: 85th-95th) and obese (BMI percentile >95th) adolescents were 31.6% and 68.4%, respectively.

After it was realized that the mothers of most adolescents participating in this study were overweight or obese (89.5%), the mothers of the adolescents were included in the study. The mean age of the mothers participating in this study was 36.26±5.70 years.

Study Design

A lifestyle intervention including diet modification and a physical activity program was applied to the adolescents and their mothers during the 16-week study period. Anthropometric measurements (body weight, height, waist and hip circumference), body composition (fat mass [FM], fat-free mass [FFM], skinfold thicknesses), systolic and diastolic blood pressure (SBP, DBP), hemoglobin, blood glucose, creatinine, uric acid, aspartate transaminase (AST), alanine transaminase (ALT), total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride, glycosylated hemoglobin, insulin, thyroid stimulating hormone (TSH), fibrinogen, and C-reactive protein (CRP) were analyzed, homeostasis model assessment of insulin resistance (HOMA-IR) was calculated, and MS criteria were evaluated at baseline and week 16.

In order to suggest proper dietary modification, the nutritional habits and food consumption were examined, and daily food consumption was calculated for each child and their mothers. After this evaluation, by taking into account age, gender and stature, an appropriate diet was given to each adolescent, and unhealthy food consumption was restricted in order to provide a maximal weekly 0.5 kg weight loss.

Lifestyle intervention, including physical activity, nutrition education, and behavior therapy, was encouraged in the study group and their mothers. Nutrition counseling that aimed to improve eating habits (i.e. increase whole-grain and fiber intake and fruit and vegetable servings; limit lower nutrient density and higher fat and calorie foods; minimize or eliminate sweetened beverages) was suggested, as it is a critical component of a successful obesity treatment program[7,9]. Regular breakfast, main meals and snacks were recommended. Moreover, dietary treatment was applied to the overweight and obese mothers of the adolescent, and the changes in the anthropometric measurements and body composition parameters were evaluated at baseline and week 16.

Among the modifications in lifestyle that were suggested to the adolescents and their families was to decrease the amount of time spent being sedentary (i.e., watching television)[9]. In its place, participants were encouraged to walk a minimum of 45 minutes daily, dance with music, increase the activity at home, and take up sportive activities.

All patients and their mothers were followed every two weeks in terms of weight management and adherence to the diet and physical activity program.

Anthropometric Measurements

The anthropometric measurements (weight, height, waist and hip circumference) were recorded, and body compositions were measured by a body composition analyzer. The growth charts for children developed by Ozturk et al.[10] were used. These charts include age- and sex-specific BMI references for children and adolescents. Children with BMI percentile $>95^{th}$ percentile were considered as obese, while those with BMI of 85^{th}-95^{th} percentiles were considered as overweight[11].

The percentiles of waist circumference developed for Turkish children and adolescents were used[12]. The ratio of waist circumference to height was calculated[13].

Triceps, biceps, and subscapular skinfold thicknesses were measured using the Harpenden Skinfold Caliper (Holtain Ltd, Brynberian, UK). Percentiles from triceps and subscapular skinfold thicknesses were evaluated[14].

The percentiles of fat percentage were determined using the charts of fat percentage percentiles developed for healthy Turkish children[15]. Fat percentage <10 was considered as underweight and ≥ 30 was considered as overweight for girls[16].

In terms of BMI values, the mothers were classified as follows: 20.0-24.9 kg/m^2 normal, 25.0-29.9 kg/m^2 overweight, 30.0- 9.9 kg/m^2 obese, and >40 kg/m^2 morbid obese[17].

Several body composition parameters; namely, BMI, basal metabolism rate (BMR), FM, FFM, total body water (TBW), and impedance were measured by bioelectrical impedance analysis (BIA) (Tanita TBF 300M) in the study group and their mothers. BIA measurements were taken in the morning after the subjects fasted for at least 12 hours (h) and after 15 minutes (min) rest. The subjects stood on the footplate electrodes keeping an upright posture so as to equalize the weight on the right and left feet[18]. According to the BIA analysis, FM index and FFM index [fat mass index = fat-mass/ (height)^2, fat-free mass index = fat free mass/ (height)^2 were calculated.

Metabolic Syndrome Parameters

The obese children were evaluated for the presence of MS according to the criteria defined by Iannuzzi et al.[19]. According to these criteria, presence of 3 out of 5 criteria (fasting glucose >110 mg/dl; triglycerides >100 mg/dl; HDL-cholesterol <45 (males), <50 mg/dl (females); waist $>75^{th}$ percentile for age and gender; SBP/DBP $>90^{th}$ percentile (age, sex, height)) was accepted as MS for children.

Systolic and diastolic blood pressures (SBP/DBP) were measured on at least three separate occasions and evaluated according to the percentiles defined by Park et al.[20].

The complete blood count, biochemical analysis (glucose, creatinine, uric acid, total protein, albumin, AST, ALT), serum lipids, CRP, fibrinogen, fasting insulin level (before the study n=16, after the study n=9), and TSH (before the study n=19, after the study n=8) were evaluated in the obese group. For the assessment of insulin resistance, HOMA-IR index[21] (before the study n=16, after the study n=9) was used.

The study was approved by the Training and Planning Coordination Office of Turkey Yüksek İhtisas Research and Training Hospital. Informed consent was obtained from all subjects and their mothers.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) 15.0 for Windows (SPSS Inc., Chicago, IL). Paired samples t test was used if the distribution of quantitative variables was normal, and Wilcoxon signed rank test was used if the distribution of quantitative variables was abnormal. Arithmetic mean, standard deviation, median, and range were used as descriptive statistics. A p-value <0.05 was considered significant.

Results

At week 16, the percentages of overweight and obese adolescents were 57.9% and 26.3%, respectively. Before the study, waist circumference measurements of all adolescents were $>95^{th}$ percentile; however, the percentage of adolescents with a waist circumference level $>95^{th}$ percentile was reduced to 63.1% at week 16.

The biceps, triceps, subscapular skinfold thicknesses and FM were found to be decreased after the 16-week period (Table I). Before the study, high SBP/DBP values were found in 21% and 52.6% of the participants, respectively. At week 16, both SBP/DBP values were found to be >95th percentile in 15.8% of the participants. The decrease in SBP/DBP values was statistically significant ($p<0.05$) (Table I).

At the beginning of the study, 42% of the adolescents (6 girls, 2 boys) had high total cholesterol. At week 16, all participants had

Table I. The Demographic, Anthropometric, Clinical and Metabolic Features Before and After Treatment and Diet

Parameters	Before treatment (Mean± SD)	After treatment (Mean± SD)	p value
Body weight (kg)	60.83±13.13	56.15±13.13	p<0.05
Height (cm)	150.42±11.12	151.89±10.58	p<0.05
Body mass index (kg/m²)	26.52±3.39	24.15±3.35	p<0.05
Waist (cm)	83.37 ±6.33	77.89 ±5.93	p<0.05
Hip (cm)	95.47±9.79	91.68±9.63	p<0.05
Waist/hip ratio	0.88 (0.72-0.97)*	0.85 (0.7-0.95)*	p<0.05
Waist/height ratio	0.56±0.04	0.51±0.03	p<0.05
Biceps skinfold thickness (mm)	10 (6-20)*	7 (4-20)*	p<0.05
Triceps skinfold thickness (mm)	25.35±4.85	20.05±5.24	p<0.05
Subscapular skinfold thickness (mm)	25±9.3	18.42±7.2	p<0.05
Systolic blood pressure (mmHg)	110 (80-150)*	100 (80-120)*	p<0.05
Diastolic blood pressure (mmHg)	75 (50-85)*	60 (50-80)*	p<0.05
Basal metabolism rate (kkal)	1585±191.67	1519.37±175.31	p<0.05
Fat mass (kg)	19.80±7.64	14.42±6.23	p<0.05
Fat mass (%)	31.77±6.8	24.82±6.14	p<0.05
Fat-free mass (kg)	41.04±7.69	41.74±7.07	p<0.05
Hemoglobin (g/dl)	13.38±1.01	13.59±0.98	p<0.05
Glucose (g/dl)	88 (76-100)*	90 (77-95)*	NS
Creatinine (mg/dl)	0.61±0.12	0.59±0.15	p<0.05
Uric acid (mg/dl)	4.64±1.27	4.28±0.99	p<0.05
Aspartate transaminase (IU/L)	23.21±6.79	20.89±4.86	NS
Alanine transaminase (IU/L)	21.95±9.66	15.26±4.25	NS
Total cholesterol (mg/dl)	180.47±42.56	157.32±22.39	p<0.05
High-density lipoprotein (mg/dl)	51.05±8.87	51.05±11.83	NS
Low-density lipoprotein (mg/dl)	106.58±37.2	90.26±24.54	p<0.05
Triglyceride (mg/dl)	112.37±47.75	80±19.72	p<0.05
HbA_1C (%)	5.70 (5-7.3)*	5.90 (4.94-7)*	NS
Fasting insulin (μIU/ml)	13.72±7.04	12.27±5.8	NS
HOMA-IR	2.92 (1.54-8.12)*	2.61 (0.76-5.35)*	p<0.05
Thyroid stimulating hormone (mLU/L)	2.56±0.99	2.75±1.33	p<0.05
Fibrinogen (g/L)	3.29±0.75	3.11±0.52	NS
C-reactive protein (mg/dl)	0.55±0.92	0.48±0.93	NS

* Median (minimum-maximum)
NS: Not significant. HOMA-IR: Homeostasis model asssessment of insulin resistance.

a total cholesterol value within normal limits. Similarly, while 31.6% of the participants (5 girls, 1 boy) had a high LDL value before the study, it was within normal limits at week 16. Triglyceride levels were high in 36.8% of the participants (4 girls, 3 boys) at the beginning of the study, and were found within normal limits after the study. The decrease in total cholesterol, LDL, and triglyceride values was statistically significant ($p<0.05$) (Table I).

Metabolic syndrome (MS) was observed in 52.6% (adolescents having 3 or 4 positive criteria of MS) of the adolescents at baseline, while it was observed in 15.8% (adolescents having 3 positive criteria of MS) at week 16, which is a statistically significant decrease ($p<0.05$). After the treatment, none of the adolescents had 4 or more of the MS criteria.

HOMA-IR value was >3.16 in 43.8% and 22.2% of the adolescents at the beginning of the study and at week 16, respectively. In the study, the decrease in HOMA-IR after 16 weeks was found to be significant ($p<0.05$). Furthermore, a decrease in uric acid levels and an increase in hemoglobin and TSH values were observed at the end of the study ($p<0.05$) (Table I). In the present study, ALT value was found high at baseline in only 1 female adolescent (BMI level was 90^{th}-95^{th} percentile, and she had low HDL, high total cholesterol and LDL, and family medical history with hypertension, diabetes, coronary artery disease), and it was within normal limits at week 16.

Family medical history included hypertension and diabetes in 63.2% (5 girls, 7 boys) and 57.9% (4 girls, 7 boys) of adolescents, respectively.

Baseline BMI values of the mothers were as follows: 10.5% had a BMI value of 20.0 - 24.9 kg/m^2 (normal), 26.3% had a BMI value of 25.0 - 29.9 km^2 (overweight), and 63.2% had a BMI value >30 kg/m^2 (obese). At week 16, the BMI values were as follows: 10.5% had a BMI value of 20.0 - 24.9 kg/m^2 (normal), 31.6% had a BMI value of 25.0 - 29.9 kg/m^2 (overweight), and 57.9% had a BMI value >30 kg/m^2 (obese). The clinical characteristics of the mothers of the adolescents before and after the program are given in Table II.

Discussion

Obese children and adolescents should be treated at the earliest convenience with diet education as well as lifestyle intervention to increase physical activity and facilitate behavioral change[22].

Nutritional lists, including daily calorie needs of the individual in addition to adequate protein intake, should be made. Treatments involving drastic calorie reduction should be avoided. It must be noted that during childhood and adolescence, weight loss should not exceed 2 kg per month because weight loss of more than this amount may cause malnutrition[23]. With such diets, adolescents still experiencing height growth will eventually return to their normal position in the growth chart.

It is essential to involve parents in the treatment

Table II. The Demographic and Anthropometric Characteristics of the Mothers of the Adolescents Before and After Treatment

Parameters	Before treatment (Mean± SD)	After treatment (Mean± SD)	p value
Body weight (kg)	81.07±12.03	77.86±10.49	p<0.05
Body mass index (kg/m²)	32.84 (23.5-37-8)*	31.10 (23.4-36.5)*	p<0.05
Waist (cm)	92.95±10.62	89 ±9.45	p<0.05
Hip (cm)	111.63±7.34	107.79±6.23	p<0.05
Waist/height ratio	0.83±0.06	0.83±0.06	p<0.05
Basal metabolism rate (kcal)	1558±13.47	1532.23±121.62	p<0.05
Fat mass (kg)	31.96±9.36	28.84±7.65	p<0.05
Fat mass (%)	37.65±5.48	36.47±4.68	p<0.05
Fat-free mass (kg)	49.09±3.88	48.96±3.37	p<0.05

* Median (minimum-maximum)

of childhood obesity and MS, as the children are influenced by their parents throughout their development. Detailed explanation of the elements of lifestyle intervention (nutrition and exercise) to the patient and the patient's family is crucial. Parents should prevent their children from consuming calories that provide no nutrients, such as carbonated beverages, candies and salted snacks. They should not reward their kids with sweets and other "junk foods". They should provide homemade food as much as possible, and should not let their children watch television while eating since it may cause over-consumption. Lifestyle intervention including diet modification and a physical activity program was applied according to these important norms to the adolescents during the 16-week study period.

When we planned to involve the parents in the treatment of obesity, we realized that the medical history of the families included hypertension and diabetes in 63.2% and 57.9% of adolescents, respectively. Further, it was realized that the mothers of most of the adolescents participating in this study were also overweight or obese (89.5%), which is in parallel with the literature, where it is reported that children of obese parents are prone to be obese[24]. In the present study, the treatment caused a significant decrease in BMI values of the adolescents and their mothers ($p<0.05$). Furthermore, due to treatments, there was a decrease in the waist-to-hip ratio and waist circumference values, both of which have been used as predictive factors for MS, and are body fat percentage indicative and a chronic disease risk determiner for adults as well as children and adolescents[25] ($p<0.05$). The waist-to-height ratio, which has been used for the diagnosis of central obesity and to determine the metabolic and cardiovascular risks independent of age and gender[13], was observed to be high at baseline; however, it was found decreased at week 16 as their weight decreased ($p<0.05$). Total cholesterol, LDL and triglyceride values of the participants were high at baseline, and they were found decreased after the study ($p<0.05$). In the present study, MS prevalence was found quite high (52.6%) at baseline. Şen et al.[26] reported a MS prevalence of 48.1%. Reinehr et al.[27] and Coppen et al.[28] reported that a lifestyle intervention in obese children decreased the MS prevalence and improved MS components; they also observed a correlation between weight loss and improvement in MS and its components. Similarly, we observed a 70% improvement in MS prevalence in the present study.

Elevated SBP and DBP are among the MS criteria[20]. Zhang et al.[29] showed in their study that hypertension and MS are asscociated with inflammation and endothelial dysfunction. Biomarkers such as CRP, soluble intercellular adhesion molecule (sICAM)-1 and sE-selectin reflect either the status of inflammation or the status of endothelial dysfunction. In our study, while there were decreases in blood pressure and MS parameters, we also observed a nonsignificant decrease in CRP.

A research has shown that exercise reduces CRP and fibrinogen concentration in adults, and that this is often independent of adiposity[30]. Fritsch et al.[31] studied 27 overweight children and administered a one-year nutrition education, exercise therapy, and psychological care lifestyle intervention, and they observed a significant decrease in fibrinogen levels. In the present study, changes in fibrinogen and CRP levels were found to be statistically non-significant ($p<0.05$), which may be due to the shorter duration of the study or because the adolescents did not exercise as part of a treatment program. We believe that the longer program will have a greater effect on CRP levels and other markers of endothelial dysfunction.

In our study, we found that the obese individuals had higher uric acid levels at the beginning of the study. Elevated serum uric acid is associated with markers of a pro-inflammatory state. Zapolski et al.[32] suggested that uric acid should be taken into consideration as a link between renal dysfunction and both pro-inflammatory and prothrombotic state in patients with MS and coronary artery disease. In our study, a significant decrease in serum uric acid values was recorded after intervention ($p<0.05$). Krzystek-Korpacka et al.[33] administered a one-year weight reduction program (diet+exercise) in 113 children/adolescents (83 completed) and observed a significant reduction in serum uric acid values. The uric acid decrease at the end of our study may have been due to increased renal blood flow caused by decreased blood viscosity or increased water intake after intervention.

Liver steatosis, known as non-alcoholic fatty liver disease, is common among obese children. Deposition of lipid within the liver is commonly associated with increased intra-abdominal fat[34]. In the present study, ALT value was found high at baseline in only one female adolescent (BMI, 90th-95th percentile; she had low HDL, high total cholesterol and LDL, and family medical history of hypertension, diabetes, coronary artery disease), and it was within normal limits at week 16. Wang et al.[35] studied 10-17-year-old obese adolescents with non-alcoholic fatty liver disease and found that after following a one-month lifestyle intervention program, ALT and AST levels significantly decreased.

Several nonrandomized studies of lifestyle intervention in obese children have also shown that decreases in BMI are associated with improvements in insulin resistance[36]. Especially the physical activity improves the insulin sensitivity. Insulin resistance (HOMA-IR >3.16) in the present study was found in 43.8% of the participants (n=16) at baseline, and at the end of the study, it had decreased to 22.2% (n=9). This decrease was not found to be statistically significant ($p>0.05$), which could be due to the low number of patients evaluated at the end of the study as well as the short duration of the study. Atabek et al.[37] reported a 37.1% insulin resistance in 148 obese children. Kolsgaard et al.[38] attained a significant decrease in HOMA-IR and insulin levels with a one-year diet and physical activity intervention program.

The measurement of the compliance of the children to the program could be evaluated indirectly by the decrease in body weight, BMI or skinfold thicknesses. However, we did not have a chance to determine which part of the two components of the program they complied with the most. Thus, we could not determine which of the two components led to the variability in the data measured. This is the limitation of our study, so further studies should be planned to determine the independent effect of the two components of the program.

Application of diet and lifestyle intervention to mothers along with adolescents motivated adolescents to get involved in the study. In the present study, a 16-week diet and lifestyle intervention program caused significant improvement in obesity and MS in both adolescents and their mothers. In order to prevent the increase in obesity and MS, which are important public health issues, obese and overweight school-age children and adolescents should be identified in schools, and they should be treated to avoid further health problems that will inevitably occur in the future otherwise.

Another important result of our study is that the diet accompanied with lifestyle intervention including regular exercise improved the results. While weight loss, decreased waist circumference and waist-to-height ratio were observed at the end of the study, improvements in insulin resistance, cholesterol and uric acid levels were also recorded. However, the decrease in the markers of inflammation, fibrinogen as well as CRP levels, was not statistically important in the present study, which may be due to the shorter duration of the study or insufficient exercise performance of the adolescents. The treatment of obesity will become more difficult as its degree increases. Thus, early and versatile treatment programs involving both diet and lifestyle intervention should be the mainstay of the treatment.

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