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Metabolic Syndrome Resolution in Children and Adolescents After 10 Weeks of Weight Loss

Without aggressive intervention, childhood obesity and the metabolic syndrome may result in lifelong physical consequences. Interventions that emphasize healthy eating and regular exercise are crucial to stop this epidemic and its ramifications. This paper discusses the incidence of the metabolic syndrome and cardiovascular risk factors before and after a weight loss program. A retrospective review was conducted in 135 children and adolescents (aged 6 to 19) who completed a 10-week medically supervised weight loss program. Outcome measures included mean change in each component of the metabolic syndrome, total cholesterol, low-density lipoprotein cholesterol, and hemoglobin A_{1c}. After 10 weeks of weight loss, a mean (SD) weight loss of 9.24 (19.5) kg was attained. Resolution of the metabolic syndrome was seen in 75.5% of children and adolescents. Weight loss can reverse metabolic syndrome and decrease cardiovascular risk in as little as 10 weeks. J Cardiometab Syndr. *2008;3:205–210.*

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Obesity is highly linked with a constellation of disorders that increase the risk of cardiovascular disease and are hallmarks of the metabolic syndrome. Diagnosis of the metabolic syndrome is identified when ≥3 of the following risk factors coexist: elevated blood pressure, elevated triglycerides, central obesity, elevated fasting blood sugar, and reduced high-density lipoprotein cholesterol (HDL-C).[1–5]

Childhood obesity is increasing at an alarming rate. The international Obesity Task Force estimates that 22 million children younger than 5 years are obese or overweight. They have also identified that 1 in 10 children are overweight, equaling approximately 155 million. Two to three percent of children aged 5 to 17 around the world are classified as obese (30 million–45 million of the 155 million).[5]

Childhood obesity is linked with dyslipidemia, atheroma, hypertension, impaired vascular function, type 2 diabetes, the metabolic syndrome, osteoporosis, insulin resistance, cardiovascular disease, and most cancers. Other health consequences of childhood obesity include bone and joint problems, sleep apnea, steatohepatitis, and gastroenterologic problems.[6]

The negative impact that obesity has on children and adolescents can prompt psychological issues such as low self-esteem, social marginalization, and stigmatization. This will have an important consequence in long-term success and happiness.[7]

There is a direct relationship between insulin resistance, resultant compensatory hyperinsulinemia, and metabolic syndrome risk factors. The altered action of insulin on lipoprotein metabolism is what results with elevated risk factors. The resistance decreases clearance of triglycerides due to decreased lipoprotein lipase activity as well as lipolysis in adipose tissue and increases synthesis of very-low-density lipoprotein particles in the liver.[7]

Obese children and adolescents are very likely to become obese adults with type 2 diabetes and its ramifications, osteoarthritis, and heart disease.[8,9] The probability of obese adolescents continuing to become obese adults is 40% to 80%.[10] The impact of obesity and its health consequence in the adult population has clearly been identified.[11–14] Extrapolate this fact to our child and adolescent population, and the greater risk of adult obesity developing in obese and overweight children could affect future generations in monumental proportions.

The World Health Organization has acknowledged that the cause of overweight and obesity is an energy imbalance between caloric intake and calories expended. They identify that overweight and obesity can be controlled by a healthy diet and increased physical activity. The issue is of such significance and concern that the World Health Organization has established a Global Strategy on Diet, Physical Activity and Health, promoting healthy diets and regular physical activity for children and adolescents.[15]

Child weight loss studies rarely address the serious comorbid condition of the metabolic syndrome. Furthermore, studies in improving and resolving the metabolic syndrome have been limited, especially with obese children and adolescents following a medically supervised, structured weight loss program. A comprehensive search was undertaken to capture all relevant studies. After reviewing over 2000 abstracts on multiple literature review sites, the author found only 4 studies similar to this study that addressed the metabolic syndrome in overweight children and

adolescents. This is the first study to the authors' knowledge that addresses resolution of the metabolic syndrome upon completion of a 10-week low-fat, high-protein, and low-carbohydrate weight loss program.

Sex and Ethnicity in Childhood Obesity

The incidence of the metabolic syndrome in children and adolescents varies by sex and ethnicity. Prevalence increases with age and is higher among racial/ethnic minorities than among non-Hispanic whites.[16] In a multiethnic national study, the metabolic syndrome was diagnosed in higher numbers in males (6.1%) than in females (2.1%).[17] Another study, however, reported that girls 5 years of age are intrinsically more insulin-resistant than boys of the same age.[18]

Cook and colleagues[17] reported that the incidence of the metabolic syndrome was greater among white youths (4.8%) and Mexican American youths (5.6%) than black youths (2.0%). Weiss and associates[2] identified similar findings in that white youths were at greater risk for the metabolic syndrome than were black youths when same cut points between the 2 races were used. Blacks (both youth and adults) have better lipid profiles (triglycerides and HDL-C) than their white counterparts.[19]

In looking at Hispanic children, Cruz and Goran[20] found that 30% of overweight Hispanic children who had a family history of type 2 diabetes had the metabolic syndrome. Weiss and coworkers[2] found that 50% of overweight Hispanic children with the metabolic syndrome had a family history of type 2 diabetes. It is thought that a greater percentage of Hispanic persons have the metabolic syndrome diagnosed, since a greater number of Hispanic youth are overweight. Mexican American children are significantly more overweight (23.7%) than white children (11.8%) beginning at age 6.[21]

Methodology

This study was a secondary data analysis of information gathered by medical staff (nurse practitioners and physicians) working at Lindora (35 medically supervised weight loss clinics in Southern California). The study population consisted of male and female children and adolescents (aged 6 through 19) completing a comprehensive 10-week weight loss program.

Data on all pediatric patients (weight, sex, age, ethnicity, body mass index [BMI], anthropometric measures, laboratory values, and physical activity) were obtained from proprietary database. The interest of the authors was to identify the impact of specific interventions (a diet consisting of approximately 1200–1500 calories, carbohydrates ranging between 60 and 100 g/d, and recommended exercise) on the metabolic syndrome and other risk factors. Data on prestudy and poststudy weight loss were identified for the following: BMI, hemoglobin A_{1c} (HbA_{1c}), total cholesterol, low-density lipoprotein cholesterol (LDL-C), anthropometric measures, and all metabolic syndrome risk factors (consisting of triglycerides, HDL-C, waist circumference, fasting blood sugar, and blood pressure).

Exclusion criteria included any serious medical condition, type 1 diabetes, renal insufficiency or liver disease, and unstable cardiovascular disease by physical examination, laboratory assessment, and history.

Changes in criteria for the metabolic syndrome (decrease in metabolic risk factors from ≥ 3 risk factors to < 3 risk factors) were the primary outcome measures. Comparisons were made before and after weight loss. Changes in BMI, total cholesterol, LDL-C, HbA_{1c}, and body weight were secondary outcome measures. Outcome measures included the percentage and amount of weight lost and mean change in each component of the metabolic syndrome.

Data Collection

The data identifying the laboratory values and anthropometric measurements were entered into proprietary computers by medical staff (nurse practitioner or MD) at different Lindora clinics in Southern California. Data on 135 children and adolescents who completed the comprehensive weight loss program since 2005 were retrieved from a proprietary database.

Children and adolescents, along with their parents, met with medical staff for an initial evaluation and physical exam. Not all children who participated in the 10-week medically supervised weight loss program at Lindora had a BMI greater than the 95th percentile. Many children and adolescents enroll in the program due to bad eating habits, obese family members, predisposition to cardiovascular risk combined with poor eating habits, or food/weight obsessions as identified by history and interview.

An initial fasting blood test was performed, which included a complete blood count with differential, a metabolic panel, and a lipid panel. BMI, waist circumference, and weight are also identified in the initial data-gathering process. Upon completion of a 10-week program, the same blood work results, along with BMI, weight, and waist circumference was recorded.

Overweight children and adolescents were educated on how to follow a low-fat, moderate-protein, lower-carbohydrate diet. A medical staff member instructed patients and parents to follow the low-fat, lower-carbohydrate (60–100 g/d) diet. In addition, they were instructed on proper documentation of the food selected from the diet provided. Participants were encouraged to eat 3 meals and 3 snacks as well as to drink 80–100 oz of water daily. They were educated on the importance of exercise and the expectations of walking at least 10,000 steps per day. Children and adolescent had access to an easy-to-read book entitled *Body Pride, an Action for Teens*[22] to be used as a reference and guide throughout the weight loss program.

Adherence to the diet was measured by self-reported daily action plans including food records and urinary ketone assessment. Participants were to complete a 24-hour recall of food intake, which was collected at their daily visits, along with self-reported number of steps taken.

The criteria for the metabolic syndrome in children younger than 12 was

Table I. Metabolic Syndrome Cut Points by Age in Males[23]

Age, y	Waist Circumference, cm		Blood Pressure, mm Hg		HDL-C, mg/dL	Triglycerides, mg/dL	Glucose, mg/dL
	NCEP ATP III (92nd)	IDF (83rd)	Systolic (92nd)	Diastolic (97th)	(26th)	(89th)	
12	94.2	85.1	121	76	44	128	100
13	96.2	87.0	123	78	43	132	100
14	98.0	88.9	125	79	41	135	100
15	99.5	90.5	126	81	40	139	100
16	100.6	91.8	128	82	40	142	100
17	101.4	92.7	128	83	40	144	100
18	101.8	93.4	129	84	40	147	100
19	102.0	93.8	130	85	40	150	100
20	102.0	94.0	130	85	40	151	100

Abbreviations: HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Foundation; NCEP ATP III, National Cholesterol Education Program Adult Treatment Panel III. Values in parentheses are percentiles for age and gender.

Table II. Metabolic Syndrome Cut Points by Age in Females[23]

Age, y	Waist Circumference, cm		Blood Pressure, mm Hg		HDL-C, mg/dL	Triglycerides, mg/dL	Glucose, mg/dL
	NCEP ATP III (72nd)	IDF (50th)	Systolic (93rd)	Diastolic (99th)	(43rd)	(89th)	
12	79.5	72.5	121	80	48	142	100
13	81.3	74.2	123	82	48	136	100
14	82.9	75.7	125	83	49	130	100
15	84.2	76.8	126	84	49	128	100
16	85.2	77.7	128	84	49	130	100
17	86.2	78.5	128	85	49	136	100
18	87.0	79.2	129	85	49	143	100
19	87.7	79.8	130	85	50	150	100
20	88.0	80.0	130	85	50	150	100

Abbreviations: HDL-C, high-density lipoprotein cholesterol; IDF, International Diabetes Foundation; NCEP ATP III, National Cholesterol Education Program Adult Treatment Panel III. Values in parentheses are percentiles for age and gender.

identified using the research of Cruz and Goran.[20] Cruz and Goran extracted norms from national and large-population studies. Children and adolescents were classified as having the metabolic syndrome if they met ≥3 criteria for the metabolic syndrome based on age and sex. Metabolic syndrome criteria in children and adolescents older than 12 were identified using the work of Jolliffe and Janssen[23] (Table I and Table II). These criteria are the most recently developed age-specific cut points for metabolic syndrome risk factors in adolescents based on the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) and International Diabetes Foundation definitions. The most recent cut points identified by Jolliffe and Janssen do not include children younger than 12.

Statistical Analysis. Metabolic syndrome risk factors (blood pressure, triglycerides, HDL-C, fasting blood sugar, and waist circumference) were identified before and after completion of a comprehensive weight loss program. Outcome measures included the percentage and amount of weight lost and mean change in each component of metabolic syndrome risk factors, BMI, total cholesterol, LDL-C, and HbA1c.

Paired *t*-tests were used to compare the different outcome measures before and after completion of the 10-week weight loss program. Values are presented as mean±SD or SE. Statistical significance was considered at $P<.05$.

Results

Characteristics of this group of 135 pediatric patients attending a medically supervised weight control program are shown in Table III. The overwhelming majority of participants were female (78%) and white (56%), though both sexes were represented, as were children of Mexican American descent. Initially, 53 of the 135 participants (39%) met ≥3 criteria for the metabolic syndrome; thus, it was diagnosed.

Mexican American youths had the highest number of mean risk factors and metabolic syndrome, even though statistical significance was not achieved (15.7±2.5 years old with the metabolic syndrome vs 16.1±2.6 without; BMI, 35.7±6.1 vs 32.2±6.4 kg/m^2). Twenty-eight percent of Mexican American participants had the metabolic syndrome (though they represented just 21% of all children in the study) vs 34% of white children (54%

Table III. Effect of Weight Loss on Metabolic Syndrome Risk Factors Among Children and Adolescents Who Initially Had the Metabolic Syndrome Diagnosed

Characteristics	Mean (SD) Change (Boys)	Change (Girls)	*P* Value (Boys/Girls)
Body weight, kg	−10.0 (5.3)	−8.4 (3.8)	<.0001/<.0001
Body mass index[a]	−3.2 (1.5)	−3.3 (1.4)	<.0001/<.0001
Waist circumference, in	−4.4 (3.1)	−3.8 (2.3)	<.0001/<.0001
FBS, mg/dL	−2.6 (6.4)	−13.3 (54.3)	<.15/<.23
HDL-C, mg/dL	−2.8 (5.8)	+ 0.5 (6.5)	<.07/<.57
TG, mg/dL	−2.9 (39.1)	−61.5 (62.6)	<.76/<.0001
SBP, mm Hg	−9.6 (13.3)	−7.4 (12.1)	<.01/<.0007
DBP, mm Hg	−4.1 (11.1)	−5.5 (9.3)	<.02/<.002
No. of metabolic syndrome criteria present	−1.2 (0.8)	−1.3 (0.8)	<.0001/<.0001
Meet criteria for metabolic syndrome, No.	−9 (53% reduction)	−31 (86% reduction)	
Meet criteria for the metabolic syndrome following weight loss by ethnicity, No. (%)[a]			
Black	1 (100)	2 (100)	
Mexican American	2 (50)	7 (64)	
Other Hispanic	1 (100)	1 (100)	
Asian	N/A	N/A	
White	4 (56)	15 (83)	
Other	1 (0)	4 (100)	

Abbreviations: DBP, diastolic blood pressure; FBS, fasting blood sugar; HDL-C, high density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglycerides. [a]Percentage of boys or girls of each ethnic group in which the metabolic syndrome resolved following weight loss.

of children in the study) and 57% of male children (27% children in the study).

Weight change after an average of 10 weeks of weight loss ranged from −24.9 to +1.8 kg, with a mean (SD) weight loss of 9.24 (19.5) kg. Changes in BMI, waist circumference, and other measures associated with the metabolic syndrome, along with the number of metabolic syndrome criteria, are shown in Table III and Figure. Though few persons of certain ethnic groups were represented, changes in metabolic syndrome criteria by ethnicity are also shown.

Weight change was significantly associated with change in BMI, waist circumference, and diastolic blood pressure in boys and girls. A significant drop in triglycerides and systolic blood pressure was also seen in girls but did not reach significance in boys despite mean decreases of 17.5% and 4.4%, respectively. A small decrease in HDL-C was seen in both boys and girls, though it did not reach statistical significance.

Change in the incidence of the metabolic syndrome was dramatic after as few as 10 weeks of weight loss (Figure). Forty (75.5%) children who initially had the metabolic syndrome no longer did following weight loss (Table V). Of the 13 (24.5%) who still had the metabolic syndrome following weight loss, there was a mean change in the number of metabolic syndrome criteria of 3.8 to 3.3. Following weight loss, the metabolic syndrome developed in 2 (1.5%) of the children who did not initially have it (Table V). In looking at correlations between weight loss and metabolic syndrome risk factors, surprisingly the only significant correlation was found between change in weight and waist circumference (r=.30, P<.01).

Paired sample t-tests revealed significant decreases in diastolic blood pressure (t (52)=4.78, P<.01), systolic blood pressure (t (52)=4.65, P<.01), triglycerides (t (52)=4.78, P<.01), and waist circumference (t (52)=11.28, P<.01) from prestudy to post–weight loss program. The t-tests failed to reveal significant changes from prestudy to post–weight loss program on fasting blood sugar (t (52)=1.37, P>.05) and HDL-C (t (52)=0.54, P>.05). The means±SD for variables pre–weight loss program and post–weight loss program are listed in Table III.

There were also significant decreases from pre– to post–weight loss program in total cholesterol (t (126)=5.77, P<.01), LDL-C (t(126)=4.47, P<.01), HbA_{1c} (t(126)=2.68, P<.01), and BMI (t(134)=12.91, P<.01). Children's and adolescents' BMI was significantly lower at the end of the 10-week comprehensive weight loss program (30.17±6.73 kg/m^2) compared with prior to the weight loss program (33.63±6.52 kg/m^2). The means±SD for each variable are identified in Table IV.

Strengths and Limitations

This study showed that a short-term (10-week) weight loss program can reduce general risk factors including those associated with the metabolic syndrome. With these data, the detection, discussion, and treatment of the metabolic syndrome can result in at least a temporary resolution of this condition.

Limitations in the current study include recall bias (although this should

be minimal since data were documented on a daily basis) and selection bias. A major limitation of this study is that it was not a randomized controlled study. Well-executed randomized controlled trials are considered the gold standard for evaluating interventions' effectiveness in the medical field. In a randomized controlled trial, the researcher can confidently attribute the difference in outcomes between intervention and control groups to be due to the intervention and no other factors.[24]

Future studies need to focus on weight loss interventions required to improve long-term weight loss success. This study does not identify long-term data on whether the participants have maintained or will maintain the weight loss and/or have redevelopment of risk factors correlating with the metabolic syndrome and other comorbidities. Investigating how youth and their families can incorporate and sustain healthy changes will be a valuable future study.

Discussion

Even modest weight loss can have a remarkable effect on metabolic markers. Positive lifestyle changes—including making proper food choices; eating frequent, small-portioned meals; consuming a reduced-carbohydrate diet; and participating in consistent moderate exercise—can prevent the natural progression of the metabolic syndrome. This 10-week medically supervised comprehensive program identifies the positive impact of a lower-carbohydrate diet resulting in weight loss.

With obesity and the metabolic syndrome increasing in parallel, the findings of the NCEP ATP III[1] report that diet and inactivity are the major contributors to the metabolic syndrome. This study affirms evidence that this emerging health problem cuts across all major ethnic/racial groups and both sexes, underscoring the need for early intervention to prevent overweight in children.[25] Without aggressive intervention, the epidemic of obesity and the metabolic syndrome will result in an epidemic of premature and quickened atherosclerotic cardiovascular events in the future.

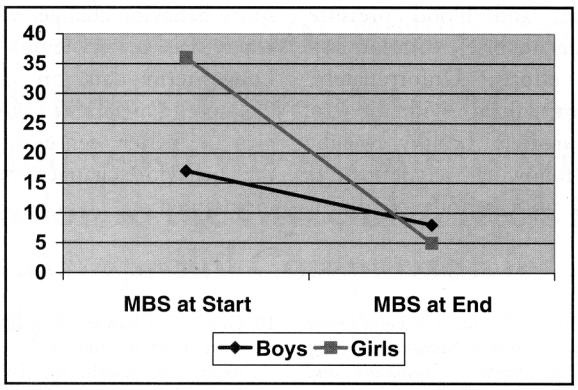

Figure. *Number of children with the metabolic syndrome (MBS) before and after weight loss.*

Table IV. Means and SDs Pre– and Post–Comprehensive Weight Loss Program

	Pre–Weight Loss		Post–Weight Loss	
Variable	Mean	SD	Mean	SD
Total cholesterol	178.71	31.10	164.34	29.13
Low-density lipoprotein cholesterol	108.26	26.33	99.10	25.84
Hemoglobin A_{1c}	5.32	0.91	5.18	0.42

Table V. Proportion of subjects with MetS pre and post intervention

	MetS – start	MetS + start
MetS – end	82 (60.7% of total)	40 (29.6% of total)
MetS + end	2 (1.5% of total)	13 (24.5% of those with MetS; 9.6% of total)

The paramount diet for modifying the metabolic syndrome is far from universal. Ultimately, weight loss resulting in improved insulin sensitivity is the key to reversing the metabolic syndrome. Even among individuals who are genetically predisposed to insulin resistance, it appears that a proper low-fat, lower-carbohydrate diet with exercise can play a large role in its reversal. An important aim is to contribute to the knowledge on the benefits of prevention, early detection, and prompt treatment of the metabolic syndrome in children and adolescents.

Some of the findings in this study are consistent with other published studies of the metabolic syndrome. Its incidence is typically higher in Mexican American men and women, for instance.[25] The current study is also consistent with a recent study in college-aged men and women that found that women are much more likely to want to lose weight,[26] and our data suggests that approximately 80% of persons attending weight loss programs are women. Men (and boys, apparently) are less likely to attend weight loss clinics,[27] which may permit comorbidities to progress further in men and boys than in women and girls.

The changes in markers of metabolic syndrome after such a brief period of weight loss was surprising. The decrease in HDL-C correlates with previous studies that show a decline during active weight loss.[28] Even among the few whose metabolic syndrome did not resolve, there were improvements in each marker except HDL-C.

These results suggest that successful resolution of the metabolic syndrome within 10 weeks of its diagnosis in children and adolescents can pay off in dividends. These children and adolescents may be well on their way to improved health.

Measures of the metabolic syndrome such as waist circumference,

blood glucose, and blood pressure respond rapidly to brief, concentrated weight loss efforts. Unfortunately, there is no convincing evidence that young age predicts healthy weight maintenance following weight loss. If the diagnosis of a serious condition spurs behavior change, would a rapid recurrence of it tempt inattention? Longer-term data on children with diagnosed metabolic syndrome may give a better sense of how long the behavior changes required were maintained.

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