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Stabilization of BMI_z is associated with a decrease in visceral fat in children with obesity

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Abstract

Context—BMI z-score (BMI_z) is commonly used to assess childhood obesity. Whether change in BMI_z predicts change in visceral fat remains unclear.

Objective—To study changes in visceral fat, cardiovascular fitness (CVF), and metabolic health over 6 months in children with stable/decreased-BMI_z versus increased-BMI_z.

Methods—Ninety children with obesity, referred for lifestyle intervention were studied (mean age 11±3.1 years, 50% girls, 22% Hispanic). Assessment included abdominal and total fat by DXA, sub-maximal VO₂ for CVF, anthropometrics, and fasting insulin, glucose, HDL-C, triglycerides, AST and ALT at 0 and 6 months.

Results—Sixty-three children (70%) showed a stable/decrease in BMI_z over 6 months. There was no significant change in total body fat between groups (−1.3±2.9% in BMI_z-stable/down vs −0.6±2.6% BMI_z-up, p=0.459); however, BMI_z-stable/down group showed a decrease in visceral fat compared to the BMI_z-up group (−258±650g versus +137±528g, p=0.009). BMI_z-stable/down group also demonstrated increased CVF (+1.2 ml/Kg/Min, p<0.001), not seen in the BMI_z-up group. Neither group had significant changes in metabolic markers.

Conclusions—Preventing BMI_z increase in obese children predicts a significant decrease in visceral fat even if total body fat is unchanged. This is often associated with increased fitness. Thus, increasing fitness level and keeping BMI stable are strategic initial goals for obese children.

Keywords

BMI; child; visceral fat

Introduction

Childhood obesity is a significant and rising global problem [1,2]. Obesity in children is defined by CDC percentiles for Body Mass Index (BMI), based on age and gender, also

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recommended by the obesity task force [3]. While other anthropometric measures can be used to evaluate body fat, BMI remains the most commonly used measure to define and assess severity of childhood obesity due to its ease of use in clinical settings and strong correlation with body fat percentage. Importantly, however, BMI does not differentiate between different areas of fat distribution in subcutaneous, visceral, and hepatic sites. Regional body fat distribution, particularly in visceral adipose tissue and hepatic fat accumulation, plays an important role in development of insulin resistance and accompanying metabolic derangements. Thus, it would be expected that central obesity, which includes visceral and hepatic adipose tissue, correlates with metabolic disease more strongly than BMI.

Other anthropometric indices to assess body fat amount and distribution include: waist circumference, ratio of waist-to-hip ratio (WHR), and skinfold thickness. Pediatric waist circumference percentiles are available from CDC [4]. Because of its correlation with visceral fat, waist circumference is included as a criterion for determining risk for metabolic syndrome in children and adolescents by the International Diabetes Federation [5]. The Obesity Task Force does not recommend routine clinical use of skinfold thickness measurements or ratio of waist to hip measurement in the assessment of childhood obesity. Literature review and task force guidelines recommend BMI as a screening tool with added waist circumference measurement for prediction of risk for cardiovascular comorbidities, PCOS, type 2 diabetes mellitus and hypertension [6,7]. It remains unclear though to what degree changes in BMI *alone* reflect changes in visceral fat and therefore metabolic health.

The aim of this study is to determine how changes in BMI standard deviation score for age (BMIz) during 6 months of lifestyle intervention in obese children related to changes in visceral fat measured by DXA, fitness measured by (VO2 max), and biomarkers of metabolic health.

Methods

This study is a retrospective analysis of obese children referred to University of Wisconsin pediatric multidisciplinary clinic for healthy lifestyle intervention. Study procedures were approved by the Health Sciences Human Subjects Committee at the University of Wisconsin- Madison.

Obese children (BMI-for-age 95 percentile), $n = 485$ and ages 4–19 years, were analyzed retrospectively. Children without complete data of anthropometric measures, metabolic markers, DXA scan and VO2 max were excluded. Criteria for inclusion were subjects who had 6 months between initial visits and follow up visit and completed DXA scan as well as exercise treadmill test for VO2 measurements. Ninety children (50% girls) fulfilled all inclusion criteria and were divided for analysis based on success at stabilizing or decreasing BMI Z-score (BMIz stable/down group) vs. those that gained in BMI Z score (BMIz up group).

Anthropometrics, metabolic markers, body composition, and exercise tolerance measurements were performed at 0 and 6 months. Measurement procedures were performed

and analyzed by the same investigators. Height was measured with a wall-mounted stadiometer to the nearest 0.1 cm. Weight was measured on a calibrated beam balance platform scale to the nearest 0.1 kg. BMI z-scores (BMI_z) were calculated using the 2000 Centers for Disease Control and Prevention (CDC) growth reference [8]. Metabolic marker analysis included fasting glucose, insulin, HDL-C, triglycerides, AST and ALT. HOMA IR was calculated from fasting glucose and insulin results. ($IR_{HOMA} = (I_0 \times G_0) / 22.5$)

Whole body scans were performed with a Norland XR-800 bone densitometer (Norland Corporation, Ft. Atkinson, Wisconsin USA) with subject in supine position by the same investigator. Tissue masses were analyzed using software version 4.6.5/2.3.1. Dual NaI detectors measure the attenuated x-ray using a pixel size of 6.5×13.0 mm and a scan speed of 260mm/sec. DXA scans were performed after patients removed metal objects or clothing containing metal components. Each scan session was preceded by a calibration routine using multiple quality control phantoms that simulated soft tissue and bone per manufacturer guidelines. STD CV: Total BMC=0.9, Lean =0.93, Fat =1.4. All DXA regions were set by the same investigator using bone landmarks.

The body composition values of total body bone, muscle and fat mass, as well as % FAT were measured by DXA. Visceral adiposity was estimated by DXA scan. The measurement of fat in abdominal region that extends from the bottom of the rib cage to the top of the pelvis was measured starting from L5 vertebrae.

VO₂ Max measurement is based on a sub maximal treadmill-based protocol standardized for obese children [9]. During the submaximal treadmill test, subjects are fitted with a heart rate monitor consisting of a chest strap and watch (Polar USA, Lake Success, New York). Immediately before testing, after being seated for 1 minute, resting heart rate (resting HR), in beats per minute (bpm) and resting blood pressure (with manual sphygmomanometer) is obtained. Individuals practice walking on the treadmill while being given instruction on proper treadmill walking technique (not holding on to bars, minimizing trunk flexion), self-selecting a brisk but comfortable walking pace; speeds range from 2.0 to 4.5 mph. Test begins at a self-selected testing speed at 0% grade for an initial 4-minute warm-up phase. The grade is then increased to 5%, maintaining the same speed. After 4 minutes, the heart rate as reported by the heart rate monitor watch is recorded (4min HR). Speed and grade are decreased during cooling down period of approximately 1 to 2 minutes. VO₂ is measured by using open circuit spirometry. An equation is used to predict VO₂max using the variables of sex, weight (kg), height (cm), heart rate (HR) after 4 minutes during the submaximal test.

Statistical Analysis

All baseline characteristics were summarized in terms of means (SD) or frequencies and percentages. Since the body composition, fitness, anthropometrics, and metabolic markers were not normally distributed, nonparametric analyses were conducted to evaluate changes in outcome parameters. Specifically, changes in body composition, VO₂ max, anthropometrics, and metabolic markers from the month 0 to the month 6 assessment within the BMI_z-stable/down and BMI_z-up groups were conducted using the nonparametric Wilcoxon signed rank test. Analogously, comparisons of changes between the two BMI_z groups were conducted using a nonparametric Wilcoxon rank sum test. All reported P-values

are two-sided and $P < 0.05$ was used to define statistical significance. Statistical analysis was conducted using SAS software (SAS Institute, Cary NC), version 9.4.

Results

Baseline characteristics were comparable between the two groups of children. Mean age in both groups were similar (11 years, range 4–19 years, in BMI Z stable/down group; 12 years, range 7–18 years BMIz up group (Table 1). Among all children, 50% each of females and males were present in initial groups. Financial class analysis revealed that 25 out of these 90 children (28%) had Medicaid/Medicare for insurance, while the remainder had private insurance. A total 20 out of 89 (22%) children were Hispanic. One child did not share his/her ethnicity. In the BMI z stable/down group there were 21% Hispanic children while in the BMI Z up group 25% of children were Hispanic. Both groups were comparable in terms of ethnicity as well as gender.

Changes in study parameters are summarized in Table 2 and Figure 1. Sixty-three children (70%) showed a stable or decrease in BMIz score after 6 months while 27 children (30%) showed an increase in BMI z score. There were no significant differences in total body fat between groups after intervention ($-1.3 \pm 2.9\%$ vs $-0.6 \pm 2.6\%$, $p = 0.459$); however, BMIz-stable/down group showed decrease in visceral fat ($-258 \pm 650\text{g}$ versus $+137 \pm 528\text{g}$, $p = 0.009$). The BMIz-stable/down group also demonstrated significantly improved VO2 max ($+1.2 \text{ ml/Kg/Min}$, $p < 0.001$), while no significant change in fitness was detected in the BMIz-up group. There were no significant changes detected in either group in metabolic markers (Table 2). In this study, measurement of waist circumference was not included as an additional anthropometric measure since it was only available in 57 out of 90 children.

Discussion

While BMI is a feasible and widely used screening tool for obesity, its usefulness in predicting changes in fat distribution during childhood over time is unknown. Previous studies have related BMIz primarily to total fat percentage, whereas this study evaluated whether change in BMIz predicts a decrease in visceral fat, the compartment of the adipose tissue considered to have greater adverse metabolic consequences. These data support that BMIz stabilization or decrease following 6 months of lifestyle intervention is accompanied by a significant decrease in visceral fat in obese children. However, while a BMIz-stable or decreased response to intervention was also associated with improved fitness, it did not cause significant changes in biomarkers of metabolic health over the 6-month study period.

While BMI has utility for screening and epidemiologic research, concerns remain about misclassification of growing children as overweight or obese when using BMI alone [6]. This study adds to knowledge regarding outpatient obesity assessment by demonstrating that, in spite of these limitations, stability or improvement in BMI Z over time is associated with a decrease in visceral fat even when total body fat is not significantly changed.

Interestingly, children in the BMIz-stable/down group showed an increase in overall fitness level as well as a decrease in visceral fat. Since fitness in childhood and adolescence is an independent predictor of metabolic health [10,11], this change supports long term health

benefits of BMI stabilization even though changes in blood biomarkers were not evident after 6 months. With more prolonged study, it can be determined whether these fitness changes of this degree will lead to subsequent detectable improvements in insulin sensitivity and lipid metabolism.

Limitations of this study include potential participation bias due to its retrospective data analysis – rather than prospective intent to treat design, focusing on children referred for lifestyle intervention who completed all evaluations (i.e. DXA, blood tests for metabolic markers, and VO2 max testing) over a 6-month period. Second, the 6 months' duration may be short enough to both overestimate adherence (compared to longer-term intervention) and underestimate effects on metabolic health. Third, fat compartment estimation was performed using DXA rather than more precise methods such as MRI [12]. However, DXA measurement of visceral obesity have been validated by studies in adults [13,14] and this technique is quick, requires no sedation, is without radiation exposure, and is tolerated well by most children. When compared with MRI, DXA is more affordable and comparable to CT scan in accuracy based on these recent studies for visceral adiposity [13]. Prior studies using DXA have also shown that BMI does not reliably indicate degree of adiposity particularly in younger children [15] leading to cautions against use of BMIz as a predictor of % FAT in children younger than 9 years. Nevertheless [16] while DXA is a more accurate measure of regional adiposity than BMI, it is not practical on a large scale due to cost and resource limitation [17–19]. Thus, clinicians continue to rely on BMI as a feasible assessment tool for obesity and weight-related disease states based on the assumption that a high BMI equals a high degree of adiposity [20]. Obesity task force also recommends using body mass index (BMI) as well as the Centers for Disease Control and Prevention (CDC) BMI percentiles to diagnose overweight or obesity in children and adolescents over 2 years of age.

Conclusions

This study demonstrates that stabilization or reduction in BMIz during lifestyle intervention – even when not accompanied by a reduction in total body fat – is accompanied by a significant decrease in visceral fat in obese children. A decrease in visceral fat appears more likely when lifestyle intervention results in an increase in overall fitness level. These findings suggest that initial goal setting for obesity treatment intervention in children include a focus on increasing fitness while (at least) preventing an increase in BMIz. More long-term follow up of these children will indicate whether sustained improvements in visceral obesity and physical fitness lead to improvements in metabolic health indicators.

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Abbreviations

BMI z:	Body Mass Index
DXA:	Dual x-ray absorptiometry

REFERENCES

1. Collaborators GBDO. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. *N Engl J Med* 2017; 377: 13–27 [PubMed: 28604169]
2. Seidell JC, Halberstadt J. The global burden of obesity and the challenges of prevention. *Ann Nutr Metab* 2015; 66 Suppl 2: 7–12
3. Must A, Anderson SE. Body mass index in children and adolescents: considerations for population-based applications. *Int J Obes (Lond)* 2006; 30: 590–594 [PubMed: 16570087]
4. U.S.Department of Health and Human Services, CDC, NCHS. Anthropometric reference data for children and adults: United States, 2007–2010 In; 2012
5. Zimmet P, Alberti KG, Kaufman F, Tajima N, Silink M, Arslanian S, Wong G, Bennett P, Shaw J, Caprio S, Group IDFC. The metabolic syndrome in children and adolescents - an IDF consensus report. *Pediatr Diabetes* 2007; 8: 299–306 [PubMed: 17850473]
6. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. *Pediatrics* 2007; 120 Suppl 4: S193–228 [PubMed: 18055652]
7. Lee S, Bacha F, Gungor N, Arslanian SA. Waist circumference is an independent predictor of insulin resistance in black and white youths. *J Pediatr* 2006; 148: 188–194 [PubMed: 16492427]
8. Albin AK, Norjavaara E. Pubertal growth and serum testosterone and estradiol levels in boys. *Horm Res Paediatr* 2013; 80: 100–110 [PubMed: 23988590]
9. Nemeth BA, Carrel AL, Eickhoff J, Clark RR, Peterson SE, Allen DB. Submaximal treadmill test predicts VO2max in overweight children. *J Pediatr* 2009; 154: 677–681 [PubMed: 19167724]
10. Vanhelst J, Fardy PS, Chapelot D, Czapllicki G, Ulmer Z. Physical fitness levels of adolescents in the Ile de France region: comparisons with European standards and relevance for future cardiovascular risk. *Clin Physiol Funct Imaging* 2016; 36: 476–481 [PubMed: 26095754]
11. Ruiz JR, Cavero-Redondo I, Ortega FB, Welk GJ, Andersen LB, Martinez-Vizcaino V. Cardiorespiratory fitness cut points to avoid cardiovascular disease risk in children and adolescents; what level of fitness should raise a red flag? A systematic review and meta-analysis. *Br J Sports Med* 2016, DOI: 10.1136/bjsports-2015-095903:
12. Karlsson AK, Kullberg J, Stokland E, Allvin K, Gronowitz E, Svensson PA, Dahlgren J. Measurements of total and regional body composition in preschool children: A comparison of MRI, DXA, and anthropometric data. *Obesity (Silver Spring)* 2013; 21: 1018–1024 [PubMed: 23784906]
13. Kaul S, Rothney MP, Peters DM, Wacker WK, Davis CE, Shapiro MD, Ergun DL. Dual-energy X-ray absorptiometry for quantification of visceral fat. *Obesity (Silver Spring)* 2012; 20: 1313–1318 [PubMed: 22282048]
14. Bi X, Seabolt L, Shibao C, Buchowski M, Kang H, Keil CD, Tyree R, Silver HJ. DXA-measured visceral adipose tissue predicts impaired glucose tolerance and metabolic syndrome in obese Caucasian and African-American women. *Eur J Clin Nutr* 2015; 69: 329–336 [PubMed: 25335442]
15. Vanderwall C, Randall Clark R, Eickhoff J, Carrel AL. BMI is a poor predictor of adiposity in young overweight and obese children. *BMC Pediatr* 2017; 17: 135 [PubMed: 28577356]
16. Styne DM, Arslanian SA, Connor EL, Farooqi IS, Murad MH, Silverstein JH, Yanovski JA. Pediatric Obesity-Assessment, Treatment, and Prevention: An Endocrine Society Clinical Practice Guideline. *J Clin Endocrinol Metab* 2017; 102: 709–757 [PubMed: 28359099]
17. Cornier MA, Despres JP, Davis N, Grossniklaus DA, Klein S, Lamarche B, Lopez-Jimenez F, Rao G, St-Onge MP, Towfighi A, Poirier P, American Heart Association Obesity Committee of the Council on N, Physical A, Metabolism, Council on A, Thrombosis, Vascular B, Council on Cardiovascular Disease in the Y, Council on Cardiovascular R, Intervention, Council on Cardiovascular Nursing CoE, Prevention, Council on the Kidney in Cardiovascular D, Stroke C. Assessing adiposity: a scientific statement from the American Heart Association. *Circulation* 2011; 124: 1996–2019 [PubMed: 21947291]
18. Boeke CE, Oken E, Kleinman KP, Rifas-Shiman SL, Taveras EM, Gillman MW. Correlations among adiposity measures in school-aged children. *BMC Pediatr* 2013; 13: 99 [PubMed: 23799991]

19. Freedman DS, Butte NF, Taveras EM, Lundeen EA, Blanck HM, Goodman AB, Ogden CL. BMI z-Scores are a poor indicator of adiposity among 2- to 19-year-olds with very high BMIs, NHANES 1999–2000 to 2013–2014. *Obesity* (Silver Spring) 2017; 25: 739–746 [PubMed: 28245098]
20. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, Hu G, Johnson WD, Kuriyan R, Kurpad A, Lambert EV, Maher C, Maia J, Matsudo V, Olds T, Onywera V, Sarmiento OL, Standage M, Tremblay MS, Tudor-Locke C, Zhao P, Church TS. Physical Activity, Sedentary Time, and Obesity in an International Sample of Children. *Med Sci Sports Exerc* 2015; 47: 2062–2069 [PubMed: 25751770]

Figure 1:
Changes in body fat, visceral fat and VO₂max from month 0 to month 6 in subjects with stable/down BMI-z scores and subjects with increased BMI-z scores.

Table 1:

Baseline Characteristics of children in study

	BMIz-stable/down N = 63		BMIz-up N = 27		Overall N = 90	
	Mean(SD)	Range	Mean(SD)	Range	Mean(SD)	Range
Age, years	11.2 (3.3)	4–19	11.6 (3.0)	7–18	11.3 (3.2)	4–19
BMI	28.7 (4.4)	19.8–41.3	27.5 (3.9)	19.9–34.1	28.3 (4.3)	19.8–41.3
BMI-z score	2.2 (0.6)	0.6–5.7	2.0 (0.5)	0.5–2.8	2.1 (0.6)	0.5–5.7
	N	%	N	%	N	%
Gender						
Female	28	44	17	63	45	50
Health Insurance						
Medicaid/Medicare	16	25	9	33	25	28
Ethnicity						
Hispanic	13	21	7	26	20	22

Table 2:

Changes in study parameters post-lifestyle intervention in groups with stable/decreased BMI z and increased BMI z.

	BMIz-stable/down: N = 63			BMIz-up: N = 27			
	Mean	SD	p-value [†]	Mean	SD	p-value [†]	p-value [‡]
Change in Total Body Fat %	-1.3	2.9	<0.001 [*]	-0.6	2.6	0.11	0.459
Change in Visceral fat (g)	-258	649	0.005[*]	136	528	0.22	0.009[*]
Change in VO2 Max	1.2	2.5	<0.001 [*]	0.5	2.4	0.76	0.089
HOMA_IR	-1.0	3.2	0.133	-6.5	-11.5	0.07	0.313
Triglycerides	-16.2	49.7	0.103	-18.4	37.3	0.13	0.977
HDL	1.6	9.0	0.395	-1.7	5.6	0.24	0.184

[†] P-value for evaluating changes within group.

[‡] p-value for comparing changes between groups

^{*} P<0.05