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Prospective BMI category change associated with cardiovascular fitness change

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Abstract

Purpose—Test the relationship of change in body mass index (BMI) percentile score group (from 6th to 8th grade) with change in cardiovascular fitness (CVF), baseline BMI_{Z-score} and CVF.

Methods—3,998 (92%) children in the HEALTHY trial provided complete data at the beginning of 6th and end of 8th grades. Height and weight were assessed according to standardized protocol. CVF was measured using the 20 meter shuttle run. Changes in BMI percentile were categorized into five groups: increased a BMI category, stayed obese, stayed overweight, stayed healthy weight, and decreased a BMI category. Data were analyzed separately by gender, controlling for race, parental education, change in pubertal stage, and baseline BMI_{Z-score} and CVF.

Results—Youth (males and females) who lowered their BMI group or remained in the healthy or overweight groups had significantly larger increases in CVF, than the stayed obese or increased a BMI category groups. But these relationships accounted for a small percentage of variance (i.e. weak relationship). Staying obese was associated with the highest baseline BMI_{Z-score}, with the second highest among those who decreased a BMI category. BMI category change accounted for the most variance in baseline BMI_{Z-score}.

Conclusions—Changes in BMI categories were substantially more strongly related to 6th grade values of BMI_{Z-score} than to CVF changes. Since pre-existing adiposity may inhibit adiposity change, changes in CVF and adiposity should be attempted prior to middle school.

Keywords

Obesity; Overweight; Longitudinal; Children

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Conflict of Interest

The authors have no conflict of interest.

The results of this study do not constitute endorsement by ACSM.

INTRODUCTION

Obesity is a prominent health problem among adults and children (20). In one longitudinal study, obesity at 10 years of age strongly predicted obesity in adulthood (21); thus, preventing childhood obesity should contribute to adult obesity prevention. Cardiovascular fitness (CVF) is a strong correlate of adiposity among children and adolescents in cross-sectional studies (2, 5, 14). Furthermore, longitudinal inverse associations between change in CVF and change in adiposity have been detected among 1,795 Chinese 8–13 year olds (yo) followed for 18 months (7); among 902 Canadian 6–15 yo followed for 12 months (15); and among 198 Greek 12–14 yo followed over two years (11). Finally, change in a composite fitness score was inversely associated with change in BMI after 3 years, but not earlier, among 345 Portuguese high school students (with no test of the effect of baseline BMI) (1). None of these studies involved lower income US ethnic minority youth who may be especially prone to obesity (18).

Several studies have reported that baseline adiposity or BMI was more important in predicting change in adiposity or BMI than change in fitness, implying that baseline adiposity could be an important barrier to change. For example, initial fat mass was the primary predictor of change in adiposity among 95 US ethnic minority 5–13 yo over 3 years, with change in fitness only weakly related (10). Similarly, baseline BMI was the primary predictor of change in BMI with baseline fitness being a weak secondary predictor among 135 Portuguese 7 yo followed for two years (16). Both latter studies included small samples.

All of these studies tested simple linear relationships which assumed that children's BMI changed in a consistent manner. However, a recent analysis of change over two and a half years among 3,993 US mostly ethnic minority 6th grade HEALTHY study participants (13) revealed that although most (65%) children remained in their initial BMI category (5th-50th percentile, 50th-85th percentile, 85th-95th percentile, above 95th percentile), 14% increased a BMI category, and 21% decreased a BMI category. In light of these findings, a test of the relationship between changes in BMI and in CVF would be more convincing if direction specific changes were revealed, i.e. increased fitness were detected among those reducing a BMI category and decreased fitness were detected among those increasing a BMI category. Using the same data set (13), this paper tested the hypotheses that children who lowered a BMI group experienced increased fitness; children who increased a BMI group experienced lower fitness; and baseline BMI was more highly associated with BMI change categories than baseline fitness or change in fitness.

METHODS

Study Design

HEALTHY was a 3-year cluster-randomized primary prevention trial. Details of the HEALTHY protocol have been described elsewhere (8). In brief, 42 U.S. middle schools with at least 50% of students eligible for free or reduced-price lunch, or belonging to an ethnic minority group, were recruited by the 7 participating centers. The study was approved by each site's Institutional Review Board, and parent consent and child assent were obtained. Schools at each site were centrally randomized to intervention or control conditions. All students were invited to participate in a health screening in fall 2006, and 57.6% of students agreed. Intervention schools received 2.5 years of a comprehensive program, which included changes to the school food environment and physical education classes, and classroom-based education that incorporated behavior change activities (6). Activities were complemented by communication and social marketing strategies. Participation of control schools was limited to recruitment and data collection.

Data Collection

Methods for data collection were reported previously, (8) and additional details are available as a supplement to the main outcome report (6). Students participated in standardized assessments using methods calibrated daily at baseline (6th grade) and end of study (8th grade). The methods employed were the same across sites and years, and a train-the-trainer procedure with criteria was employed. Height and weight were measured by trained, certified study staff using the Prospective Enterprises PE-AIM-101 stadiometer and the SECA Corporation Alpha 882 electronic scale. Measurement of student cardiovascular fitness (CVF) was based on the number of laps completed during the 20-meter shuttle test (20-MST)(8). Participants ran back and forth between two lines set 20 meters apart during a Physical Education class. Youth participated in a practice session just before the 6th grade CVF assessment. The running pace was determined by audio signals emitted from a pre-recorded CD. The test was completed when the participant was not able to complete the distance at the stipulated pace on two laps. The laps were used to predict $\text{VO}_2 \text{ Max}$ ($\text{ml kg}^{-1} \text{ min}^{-1}$), using the equation of Leger and colleagues (12). Pubertal status was self-reported using the Pubertal Development Scale (19) and converted to the pubertal stage groups of Tanner (3). The scale was administered to males and females separately in a private area, with oral instructions provided by trained study staff from a written script. All data were collected in the morning.

Ethnicity and race were self-reported by students. Because participants frequently misunderstood the distinction between ethnicity and race, the information from the separate items was combined: anyone checking 'Hispanic or Latino' ethnicity was classified as Hispanic; non-Hispanics choosing only 'Black or African American' race were classified as Black; non-Hispanics choosing only 'White' race were White; all other response categories were combined into 'Other.' A parent or guardian reported the highest level of household education and history of diabetes in first-degree blood relatives.

Statistical Methods

BMI percentile for age and sex was calculated using Centers for Disease Control reference charts (4). Students with a BMI < 85th percentile were classified as healthy weight. Youth with BMI 85th but < 95th percentile were classified as overweight; and those 95th percentile as obese. Five categories were created to examine BMI percentile shifts from 6th to 8th grade (categories with small numbers were collapsed): 1. increased a category (i.e. healthy weight to overweight or obese; or overweight to obese); 2. stayed obese; 3. stayed overweight; 4. stayed healthy weight; and 5. decreased a category (i.e. overweight to healthy weight; or obese to overweight or healthy weight).

We were interested in directional correlates of BMI category changes. In a longitudinal analysis, change in a dependent variable would be a function of the baseline value of the predictor and change in the predictor. Thus, we analyzed both baseline CVF and CVF change as correlates of BMI category change. We also analyzed baseline BMI_{Z-score}; and controlled for baseline BMI_{Z-score} when assessing change in CVF and baseline CVF, since other studies have indicated baseline BMI as a strong predictor (10, 16).

Descriptive statistics including means, standard deviations, and percents were calculated for all variables. Linear mixed models (LMM) examined whether BMI change categories predicted CVF changes, baseline BMI_{Z-score} and baseline CVF. The models were stratified by gender and adjusted for variability within and between schools, race/ethnicity, change in pubertal stage, and head of household education level. When CVF change was the dependent variable, the model controlled for baseline CVF and baseline BMI. All pairwise

comparisons of means were conducted using Tukey's procedure. SAS 9.2 statistical software (SAS Institute Inc, Cary, NC) was used for all analyses.

RESULTS

Of the 4,603 students in the HEALTHY cohort, 4,363 (95%) completed assessments at baseline and end of study. Of these, 3,998 (92%) finished the 20-meter shuttle test at both baseline and end of study. Students averaged 11.3 years of age in 6th grade, and 47.9% were male (Table 1). More than half the sample was Hispanic (55.6%) and the highest level of education of head of household was high school graduate or less for 36.8% of families.

Shifts in BMI category related to changes in CVF, baseline BMI_{z-score} and baseline CVF are presented in Table 2. For males, there were no differences in CVF change between the increased a BMI category and stayed obese, or between the increased a BMI category and stayed overweight groups. There was no difference in CVF change among the smaller three groups. However, change in CVF was smaller for the increased a BMI category and stayed obese groups, than in the other three groups. For females, there was also no difference in CVF change between the increased a BMI category and stayed obese groups, nor among the stayed obese, stayed overweight, and stayed healthy groups. The decreased a BMI category group had a significantly larger increase in CVF than the increased a BMI category or stayed obese groups (top row of Table 2).

Males in the stayed obese category had significantly lower baseline CVF, than all the other groups, which were not different from each other (middle row of Table 2). Among females, the stayed overweight and stayed healthy groups had higher baseline fitness than the other groups, except for the increased a BMI category group.

For males and females, the stayed obese group had the highest baseline BMI_{z-score} ($\bar{X}_{\text{males}} = 1.93$ BMI_{z-score} units, $\bar{X}_{\text{females}} = 2.01$ BMI_{z-score} units) with the second highest being among those who decreased BMI category (bottom row of Table 2). Pair-wise comparisons indicated that there was strong evidence ($p < 0.001$) of differences in baseline BMI_{z-score} between all groups.

Among these models, BMI category change alone accounted for the most variance in baseline BMI_{z-score} (80.8% and 80.7%), followed by small percents of variation in all other models (next to last column in Table 2).

DISCUSSION

On average, all youth (male and female) experienced some improvements in CVF, even after controlling for baseline CVF. Males and females who increased a BMI group or stayed obese experienced smaller increases in CVF than the other groups. The data presented here, therefore, do not indicate directionality in CVF change related to change in BMI_z as originally defined among males or females, but the smaller increases in the increased a BMI category or stayed obese groups suggest that change in CVF was related to change in BMI_{z-score}.

There were larger increases in CVF change among males. This pattern of results may indicate that a change in BMI category may require a greater increase in fitness among boys than girls, perhaps due to the higher levels of baseline fitness among males in all BMI change categories; or it is more difficult to get fitness increases in females. Since the analysis design does not allow us to infer causality, it is also possible that change in BMI category induced changes in CVF.

As hypothesized, the most dramatic findings were the high percentages of variance accounted for in baseline BMI_z score by change in BMI category (81.4% for boys, 81.7% for girls). This is similar to published findings with BMI (11, 16), but extends the results to a larger sample of lower income ethnic minority middle school children. This pattern indicates that pre-existing factors (baseline body status) were more closely related to body status change than CVF change, even though substantial changes were obtained in CVF (+6.87 ml kg⁻¹ min⁻¹ for 8th grade boys who decreased weight status, similar to that from an intervention study (17)). The strength of relationship of these strong pre-existing factors could be due to biological factors (e.g. genetic factors), personal habits (e.g. usual level of physical activity), social factors (e.g. parenting, peer influences) or the physical environment (e.g. proximity to activity promoting parks). Further research on these issues would benefit from multilevel models that reflected how these factors interrelate.

The highest baseline BMI_{z-score} was found in the stayed obese group (for males and females) with the second highest baseline BMI_{z-score} in the decreased a BMI category group. This suggests that the obese were at a serious disadvantage to lose weight, but the youth who lowered a BMI_{z-score} category also started high on baseline BMI_{z-score}. Youth who stayed obese started with lowest baseline fitness, and became progressively comparatively worse. The decline in fitness in the stayed obese group may indicate an age related decline in this group, or some additional barrier encountered.

The current study had significant strengths including the large, multi-ethnic sample from across the U.S.; and assessments collected by trained, certified staff using standardized procedures. Limitations include the schools and youth who participated may not be representative of all high-risk U.S. schools or students; not having the same staff measure height and weight in 6th and 8th grades; the truncation of the BMI_{z-score} at the upper and lower ends of the distribution required us to statistically treat baseline BMI_{z-score} as a dependent variable, whereas we interpreted conceptually as an independent variable; all the analyses were correlational thereby limiting inferences that can be made; the measure of fitness may indicate other components of fitness, not just CVF; and the surfaces in the schools may have differed, which may have contributed to error in assessing fitness.

In summary, changes in BMI categories were substantially more strongly related to baseline BMI_z values than to changes in CVF or baseline CVF. To minimize this possible inhibiting effect of existing BMI, changes in body status should be attempted by physical training, dietary change and/or reduced sedentary behavior (9), well prior to middle school, when levels of obesity will be lower and pose fewer barriers to change.

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HEALTHY intervention materials are available for download at <http://www.healthystudy.org/>

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Table 1
Student Characteristics (n=3998) in sixth and eighth grades, and changes in characteristics

	Grade 6				Grade 8				Change from 6 to 8			
	Male		Female		Male		Female		Male		Female	
	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std
TOTALS									1914	(47.9)	2084	(52.1)
Race/ethnicity (n, %)												
Hispanic	1063	55.54	1159	55.61								
Non-Hispanic Black	320	16.72	381	18.28								
Non-Hispanic White	383	20.01	372	17.85								
Other	148	7.73	172	8.25								
Pubertal stage (n, %)												
Stage 1	288	15.05	116	5.57	24	1.25	2	0.10	81	4.23	41	1.97
Stage 2	741	38.71	274	13.15	182	9.51	11	0.53	463	24.19	601	28.84
Stage 3	704	36.78	878	42.13	921	48.12	128	6.14	817	42.69	901	43.23
Stage 4	106	5.54	681	32.68	754	39.39	1564	75.05	404	21.11	354	16.99
Stage 5	7	0.37	68	3.26	26	1.36	367	17.61	74	3.87	103	4.94
Missing	68	3.55	67	3.21	7	0.37	12	0.58	0	0.00	6	0.29
									missing		78	3.74
Highest education level attained by head of household (n, %)												
High school graduate and less	655	34.22	816	39.16								
Some college and above	696	36.36	698	33.49								
Missing	563	29.41	570	27.35								
BMI percentile (mean, sd)	75.53	24.73	72.72	24.56	73.32	24.44	73.47	22.81	-2.21	11.69	0.76	11.53
BMI z-score (mean, sd)	0.98	0.93	0.85	0.90	0.88	0.91	0.85	0.84	-0.10	0.41	-0.003	0.38
BMI status difference between Grades 6 and 8 (n, %)												
Increased									103	5.38	151	7.25
Stayed Obese									467	24.4	405	19.43
Stayed Overweight									170	8.88	223	10.7
Stayed Healthy									843	44.04	1030	49.42
Decreased									331	17.29	275	13.2

	Grade 6						Grade 8						Change from 6 to 8					
	Male			Female			Male			Female			Male			Female		
	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std	n, mean	%, std		
VO ₂ (mean, sd) (ml kg ⁻¹ min ⁻¹)	41.43	4.24	40.02	3.13	47.62	5.39	43.49	3.89	6.18	4.71	3.47	3.62						

Legend: BMI = Body Mass Index; WC = Waist Circumference; CV = Cardiovascular; VO₂ = Volume of Oxygen squared (cardiovascular fitness)

Table 2

Cardiovascular Fitness Change, Baseline Cardiovascular Fitness, and Baseline BMI_Z-score by BMI Category Change for Boys and Girls Separately

Main IV Category	Least Squares Means		Percentage Variance Accounted for	
	Estimate	Std Error	BMI Category Change	BMI Category Change & Covariates
DV: CV FITNESS CHANGE (Δ ml kg⁻¹ min⁻¹)				
Male				
Increased	4.06bc	0.73	6.7%	14.2%
Stayed Obese+	2.79b	0.67		
Stayed Overweight	5.61ac	0.69		
Stayed Healthy	6.60a	0.64		
Decreased	6.87a	0.64		
Female				
Increased	2.03a	0.62	2.2%	13.9%
Stayed Obese+	2.80ac	0.64		
Stayed Overweight	3.54bc	0.62		
Stayed Healthy	3.71bc	0.59		
Decreased	3.98b	0.62		
DV: BASELINE CV FITNESS (ml kg⁻¹ min⁻¹)				
Male				
Increased	40.63a	0.61	2.0%	26.6%
Stayed Obese+	38.96b	0.55		
Stayed Overweight	40.77a	0.58		
Stayed Healthy	41.34a	0.53		
Decreased	40.77a	0.53		
Female				
Increased	38.58ac	0.52	1.5%	17.9%
Stayed Obese+	37.60bc	0.54		
Stayed Overweight	39.14a	0.52		
Stayed Healthy	39.32a	0.50		
Decreased	38.30c	0.52		
DV: BASELINE BMI_Z				
Male				
Increased	0.91a	0.07	80.8%	81.4%
Stayed Obese+	1.93b	0.05		
Stayed Overweight	1.31c	0.06		
Stayed Healthy	0.01d	0.05		
Decreased	1.53e	0.05		
Female				

Main IV Category	Least Squares Means		Percentage Variance Accounted for	
	Estimate	Std Error	BMI Category Change	BMI Category Change & Covariates
Increased	1.04a	0.07	80.7%	81.7%
Stayed Obese+	2.01b	0.07		
Stayed Overweight	1.36c	0.07		
Stayed Healthy	0.10d	0.06		
Decreased	1.54e	0.07		

Legend: DV = dependent variable ; CV = cardiovascular

Common letters after an estimate indicate no statistically significant difference between those two estimates for that dependent variable within that gender grouping; the second set of percentage variance estimates reflect controlling for school, race/ethnicity, change in pubertal status, and head of household education level in all analyses, plus baseline BMI for change in CVF.