Indicated Prevention of Adult Obesity

How Much Weight Change Is Necessary for Normalization of Weight Status in Children?

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Objective: To investigate the notion of indicated prevention—helping overweight or obese youth attain nonoverweight status to prevent adult obesity—by examining weight-for-height changes needed to normalize weight status in youth who are growing.

Design: We determined the amount of weight-for-height change necessary for overweight or obese youth to achieve non-overweight status using linear mixed modeling of longitudinal growth patterns and using Centers for Disease Control and Prevention weight thresholds corresponding to the age- and sex-adjusted body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) below the 85th percentile. Mean weight changes among children who achieved nonoverweight status at 1 and 2 years after treatment were calculated.

Setting: Weight control programs at 3 research institutions.

Participants: A total of 669 overweight or obese children aged 8 to 13 years.

Intervention: Family-based behavioral weight control treatment.

Main Outcome Measure: Weight.

Results: Relatively small weight changes (range, −7.55 to +3.90 kg) were necessary for children to achieve nonoverweight status after 1 year; this was most pronounced among younger children (range, −2.90 to +3.36 kg for children aged 8-10 years) and children closer to the 85th BMI percentile (range, +2.44 to +3.90 kg for children at the 90th BMI percentile). Observed weight changes of children who achieved nonoverweight status following treatment were similar to estimates based on Centers for Disease Control and Prevention normative data.

Conclusions: Attaining nonoverweight status in childhood is possible with modest weight loss or, in some circumstances, by slowing weight gain, and may help prevent adult obesity. Future research should investigate how much intervention is needed to shift the growth trajectory to nonoverweight status and how much weight-for-height change is needed to improve other health outcomes in adulthood.

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OBESITY IS A MAJOR PUBLIC health concern. Approximately 34% of adults and 17% of children in the United States are obese[1,2] and at risk for adverse health sequelae.[3] Obesity is a leading cause of preventable death,[4] accounting for 5.7% of national health care costs.[5] Obesity also presents a major burden to the individual, resulting in decreased productivity, lost wages, and reduced quality of life.[6] Pediatric obesity (PO) tends to track into adulthood,[7] and if untreated, approximately half of overweight children will remain overweight or obese as adults.[8,9] Conversely, reversal of PO may minimize many negative health outcomes with which adult obesity is associated.[10] Pediatric obesity thus represents an important point of intervention for preventing adult obesity and associated complications.

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Given the contribution of broad environmental factors (eg, food availability and opportunities for physical activity) to the development and maintenance of obesity,[10] there has been increased interest in the development of school- and community-based prevention programs. However, universal prevention programs have shown limited efficacy,[11] likely due to the limited focus on individual- or family-level behaviors. Thus, a selective approach may be more efficient.

Unlike universal prevention, which involves populations as a whole, indicated prevention involves youth who are already overweight or obese and thus more likely to track their excess weight into adulthood.[7,12] Targeting these children is recommended for many reasons. Children are often more successful in weight control programs than adults,[13] perhaps because their dietary and physical activity habits are less ingrained and more amenable to change.[14] Given associations between duration of obesity and adverse medical consequences,[15,16] children may be less likely than adults to present with comorbidities that could complicate treatment. Finally, and most pertinent to the current study, interventionists can take advantage of children's concomitant height growth, such that relatively modest weight changes are needed to produce significant reductions in markers of overweight status.[17] For these reasons, targeted intervention approaches may be most efficacious for preventing adult obesity.

It is currently recommended that overweight and obese children lower their body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) below the 85th percentile for age and sex.[18] However, given individual differences in expected height growth, it is often difficult for health care providers to make specific recommendations regarding how much weight change is needed for patients to achieve nonoverweight status. Centers for Disease Control and Prevention (CDC) growth charts can assist with treatment planning; however, they are limited by the normative sample and cross-sectional nature of the data[19] and do not account for factors unique to overweight samples, such as earlier pubertal timing.[20]

This study sought to provide estimates of the amount of weight change, given expected height changes, needed for overweight and obese children to achieve nonoverweight status during 1 and 2 years. These estimates can be used as guidelines for indicated prevention programs. Data from PO clinical trials (which seek to maximize reductions in children's relative weight) are useful in this regard because they can be used to assess how much weight change, relative to normative height changes, is needed to produce significant decreases in children's relative weight. Our estimates should be validated using prospective research on the amount of weight-for-height changes necessary to shift children from a trajectory of adult obesity and adverse health outcomes to a reduced risk of adult obesity and more positive health outcomes.

Height growth data from 669 overweight and obese treatment-seeking children were used to determine age- and sex-specific weight thresholds for achieving a BMI below the 85th percentile.[19] Next, we provided weight loss targets for hypothetical children to achieve nonoverweight status, incorporating expected height growth estimates from our empirical sample. Secondary aims were (1) to compare our empirically derived estimates of weight changes necessary for overweight and obese children to achieve nonoverweight status with those derived using CDC normative, cross-sectional data; and (2) to examine actual weight change among youth who converted from overweight/obese to nonoverweight status, or from obese to overweight status, during 1- and 2-year follow-ups. We aimed to provide these easily accessible reference data, to be used in tandem with one another, to assist health care providers in choosing short- and long-term treatment targets for their overweight and obese patients.

METHODS

PARTICIPANTS

Participants were 669 overweight and obese children (mean [SD] BMI percentile, 96.4 [1.6]); 64.6% were girls, and the mean (SD) age was 10.2 (1.3) years (range, 8-13 years). Data were drawn from PO treatment studies at 3 research institutions (University of Pittsburgh, Pittsburgh, Pennsylvania; University at Buffalo, Buffalo, New York; and San Diego State University/University of California at San Diego, San Diego), with basic aspects of family-based behavioral treatment common to all studies. These included the Traffic Light Diet; a physical activity program; behavioral treatment components such as self-monitoring, stimulus control, goal-setting, and reinforcement; parenting skills; and targeting both the parent and child[21,22] (**Table 1**). Each study was approved by the respective institutional review board. To be included in the current study, participants had to have height data available for at least 1 year after treatment; moreover, these data had to have been collected when the child was between the ages of 7.75 and 13.25 years.

STATISTICAL ANALYSIS

Analyses were conducted using SPSS, version 16.0 (SPSS, Inc). Linear mixed models were used to determine children's height changes during 1-year periods, starting at age 8 years and ending at age 13 years. Each model used the children's exact age at the time of measurement to predict measured height. For each 1 year of chronological age, observations within 3 months above or below the age thresholds were included to maximize estimation around each year's model (eg, a child initially aged 7.75 through 8.25 years would be included in the 8- to 9-year age category). Separate models were developed for boys and girls within each age category, producing a total of 10 models. The slope estimates from each model describe the change in height during a 1-unit (ie, 1-year) increase in age. Because of differing attendance at follow-up assessments, some children were represented in multiple age categories, whereas others were represented in only 1 category.

Using 2000 CDC child BMI percentiles,[19] we calculated weight thresholds at the 85th BMI percentile for children of differing ages and heights. The CDC data were also used to calculate the amount of weight change needed for hypothetical children of different ages and baseline BMI percentiles (ie, 90th, 95th, and 97th percentiles) to shift to nonoverweight status (ie, less than the 85th BMI percentile). Baseline height and height growth data from our mixed-model analyses were used to derive these latter estimates. We also calculated weight change targets for children of different ages and different baseline BMI percentiles to shift to nonoverweight status, based solely on CDC normative data. Height data for these latter estimates were based on the 50th height percentile; differences in height between age cohorts from the CDC data were used as a proxy for longitudinal height growth. Weight change targets based on our longitudinal data and CDC normative data were compared using correlations.

Means, SDs, and ranges of observed weight changes were calculated for those youth from our longitudinal sample who converted from overweight or obese to nonoverweight status, or from obese to overweight status, during 1- and 2-year follow-

Table 1. Baseline Sample Characteristics by Study[a]

Citation	Location	Follow-up, mo	No.	Girls, No. (%)	Age, Mean (SD), y	Nonwhite, No. (%)[b]	Mean (SD) BMI	Mean (SD) BMI z Score	Mean (SD) BMI Percentile
Epstein et al[23]	Pittsburgh	120	47	31 (66.0)	10.1 (1.5)	. . .	24.77 (3.08)	1.88 (0.40)	95.14 (2.63)
Epstein et al[24]	Pittsburgh	120	35	28 (80.0)	10.5 (1.4)	. . .	25.54 (2.42)	1.91 (0.32)	95.77 (2.32)
Epstein et al[25]	Pittsburgh	120	38	30 (78.9)	10.9 (1.1)	. . .	25.86 (3.07)	1.86 (0.37)	95.16 (2.63)
Epstein et al[26]	Pittsburgh	120	41	30 (73.2)	10.6 (1.3)	. . .	26.63 (3.66)	2.00 (0.35)	96.02 (1.81)
Epstein et al[27]	Buffalo	24	80	54 (67.5)	10.4 (1.2)	4 (5.0)	27.86 (3.06)	2.17 (0.26)	96.73 (0.90)
Epstein et al[28]	Buffalo	24	59	31 (52.5)	10.4 (1.1)	2 (3.4)	27.55 (3.06)	2.16 (0.27)	96.68 (1.17)
Epstein et al[29]	Buffalo	12	60	30 (50.0)	10.3 (1.2)	3 (5.0)	27.34 (3.54)	2.15 (0.29)	96.60 (1.57)
Epstein et al[30]	Buffalo	24	63	38 (60.3)	9.9 (1.3)	5 (7.9)	27.73 (2.65)	2.24 (0.22)	96.97 (0.18)
Goldfield et al[31]	Buffalo	12	24	17 (70.8)	10.0 (1.3)	0 (0)	26.84 (3.17)	2.12 (0.27)	96.66 (1.10)
Epstein et al[32]	Buffalo	24	37	22 (59.5)	10.2 (1.2)	1 (2.7)	30.00 (4.37)	2.35 (0.31)	96.79 (0.86)
Epstein et al[33]	Buffalo	24	35	16 (45.7)	10.5 (1.1)	5 (14.3)	29.53 (4.18)	2.27 (0.30)	96.73 (1.49)
Wilfley et al[22]	San Diego	24	150	105 (70.0)	9.9 (1.3)	48 (32.0)	27.59 (3.41)	2.20 (0.30)	96.68 (1.18)
Full sample	. . .	. . .	669	432 (64.6)	10.2 (1.3)	68 (13.4)	27.36 (3.51)	2.13 (0.33)	96.43 (1.61)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).
[a] All values are for children. Numbers refer to participants included in the current study and do not necessarily reflect the sample sizes for the original studies.
[b] Race/ethnicity data were not available for all studies; percentage of nonwhites for the full sample reflects the percentage of available subjects.

ups. Because of the small sample sizes, categories of participants were collapsed by age and sex.

RESULTS

Table 2 presents observed height growth for overweight and obese children during 1-year periods, starting at age 8 years and ending at age 13 years. These values could be added to a child's current height to estimate height growth during the coming year. The 95% CIs are provided as more and less conservative estimates of growth during different age categories. For instance, if a child has tended to grow slowly relative to the average child, the lower end of the 95% CIs may be advisable to predict annual height growth.

The eTable (http://www.jamapeds.com) presents weight thresholds corresponding to the 85th percentile for age- and sex-adjusted BMI. Given a child's sex, age, and height, these tables supply the minimum weight that would indicate overweight status. Any weight below the thresholds demarcates a healthy weight range. Pediatric obesity interventions should help children achieve a weight lower than these thresholds to prevent adult obesity.

Table 3 provides sample weight change targets for hypothetical children at the 90th, 95th, and 97th percentiles for age- and sex-adjusted BMI. For the longitudinal estimates, weight loss targets are based on hypothetical children of average height and assuming average growth during 1-year intervals, based on our longitudinal sample. For the cross-sectional estimates, weight loss targets are based on children at the 50th height percentile from the CDC normative sample; height changes for the CDC sample were based on cross-sectional differences in observed heights between age cohorts for children at the 50th percentile for height. Using these 2 data sets, we determined the amount of weight change needed to move children from the 90th, 95th, or 97th age- and sex-adjusted BMI percentile to the 85th age- and sex-adjusted BMI percentile during 1 year. Correlations between weight change targets based on our longitudinal data and on CDC data were in the large range (*r* range, 0.59-0.97). These targets are examples only; children exhibiting smaller-than-average height or height growth would require greater weight loss in order to achieve nonoverweight status in 1 year. Children who are taller than average or who demonstrate greater-than-average growth would go further below the 85th BMI percentile than projected. For more precise weight loss targets, health care providers are advised to use the height-specific weight thresholds provided in the eTable. After estimating a patient's anticipated height growth for the coming year, select the weight threshold corresponding to the patient's age in the coming year and compute the difference between the patient's current weight and the weight threshold value.

Table 2. Observed Height Growth During 1 Year Based on Longitudinal Data for Overweight Children Aged 8 to 13 Years[a]

Age Category, y	Observed Growth (SE), cm	95% CI
Boys		
8-9 (n = 21)	5.01 (0.39)	4.19-5.82
9-10 (n = 71)	5.72 (0.28)	5.16-6.27
10-11 (n = 103)	5.16 (0.21)	4.73-5.58
11-12 (n = 109)	5.74 (0.19)	5.37-6.12
12-13 (n = 81)	6.61 (0.21)	6.19-7.03
Girls		
8-9 (n = 67)	6.28 (0.21)	5.86-6.69
9-10 (n = 140)	6.17 (0.17)	5.83-6.51
10-11 (n = 172)	6.35 (0.17)	6.01-6.68
11-12 (n = 171)	5.88 (0.15)	5.59-6.17
12-13 (n = 127)	5.05 (0.19)	4.68-5.43

[a] Children were measured at least twice within each 1-year age category.

Table 4 presents observed weight changes for children who moved from overweight or obese to nonoverweight status, or from obese to overweight status, during 1- and 2-year follow-ups. Some of the children who shifted to nonoverweight status were considerably lower

Table 3. Weight Change Targets for Shifting Hypothetical Children to the 85th Age- and Sex-Specific BMI Percentile During 1 Year[a]

	Baseline Height, cm		Weight Change Targets, kg					
			90th		95th		97th	
Age Category, y	Longitudinal Data, Mean (SD)	Cross-Sectional Data, 50th Percentile	Longitudinal Data	Cross-Sectional Data	Longitudinal Data	Cross-Sectional Data	Longitudinal Data	Cross-Sectional Data
Boys								
8-9	134.17 (5.20)	128.12	2.44	2.64	−0.04	0.39	−2.14	−1.53
9-10	140.02 (5.27)	133.73	2.99	2.52	−0.16	−0.35	−2.88	−2.84
10-11	144.12 (6.03)	138.82	2.75	2.52	−1.01	−0.97	−4.28	−4.00
11-12	149.59 (6.96)	143.73	3.21	3.00	−1.22	−1.09	−5.05	−4.62
12-13	155.19 (5.95)	149.31	3.90	4.12	−1.15	−0.56	−5.49	−4.58
Girls								
8-9	133.45 (5.47)	127.83	3.22	2.59	0.47	0.07	−1.82	−2.03
9-10	139.56 (6.17)	133.13	3.36	2.61	−0.05	−0.49	−2.90	−3.08
10-11	145.00 (6.04)	138.21	3.57	3.25	−0.52	−0.47	−3.93	−3.57
11-12	150.80 (6.49)	144.26	3.30	4.07	−1.53	−0.35	−5.55	−4.03
12-13	156.14 (6.36)	151.49	2.65	3.17	−2.91	−2.07	−7.55	−6.43

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).
[a]Weight-change targets for boys and girls from the longitudinal data are based on observed height and growth from the mixed model analyses of our longitudinal sample of overweight children. Weight-change targets for boys and girls from the cross-sectional data are based on heights at the 50th percentile and differences in stature between age cohorts from the Centers for Disease Control and Prevention normative sample.

Table 4. Observed Weight Changes for Children Who Lowered Their Weight Status During 1- and 2-Year Follow-ups[a]

	Weight Change at 1-y Follow-up, kg		Weight Change at 2-y Follow-up, kg	
Baseline BMI Percentiles	No.	Mean (SD) (Range)	No.	Mean (SD) (Range)
Children Who Converted From Overweight or Obese to Nonoverweight Status				
90th-95th percentiles	20	−2.4 (1.9) (0.5 to −7.0)	11	4.1 (3.3) (8.6 to −0.7)
95th-97th percentiles	12	−6.8 (4.1) (−0.7 to −12.6)	10	0.6 (4.7) (7.3 to −5.1)
>97th percentiles	16	−10.3 (4.0) (−3.2 to −18.4)	15	−6.8 (5.0) (−0.9 to −17.1)
Children Who Converted From Obese to Overweight Status				
95th-97th percentiles	39	0.7 (3.4) (7.1 to −6.1)	20	9.7 (5.5) (19.5 to −2.8)
>97th percentiles	61	−4.8 (4.6) (3.5 to −16.8)	42	2.1 (4.9) (14.1 to −10.0)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).
[a]Participants were drawn from all available studies, thus some participants are included at only 1 follow-up time point while others were available at both follow-up time points.

than the 85th age- and sex-adjusted BMI percentile at 1-year (range, 33.3-84.9) and 2-year (range, 48.1-84.9) follow-up; thus, the values provided in this table may overestimate the amount of weight change needed to convert to nonoverweight status (eg, the child who had lost 18.4 kg at the 1-year follow-up initiated treatment at the 97th BMI percentile and achieved a BMI percentile of 33.3 at the 1-year follow-up). The average overweight child should not be expected to move so far below the 85th BMI percentile; indeed, more modest weight changes can be expected to result in a shift to nonoverweight status, as demonstrated in Table 3.

COMMENT

This study provides estimates of weight change necessary for overweight or obese children to shift to nonoverweight status. The values differ by age and sex but, more important, illustrate that large weight losses may not be necessary to achieve nonoverweight status. For children closer to the 85th BMI percentile who are growing at the expected rate, even modest weight *gain* during 1 year can normalize weight status, given concomitant height changes. For example, an 8-year-old girl at the 90th BMI percentile could gain approximately 3 kg to achieve nonoverweight status in 1 year. Conversely, gaining 5 kg would result in BMI maintenance at the 90th percentile in 1 year. This minimal difference of 2 kg indicates that drastic behavioral changes are likely unnecessary for attainment of nonoverweight status for some youth. Even for more severely overweight children, relatively small weight losses of 2 to 7 kg can lead to nonoverweight status during 1 year; this translates to a weight loss of approximately 0.04 to 0.13 kg per week, well within clinical recommendations for children.[18]

More severely obese children (ie, BMI ≥99th percentile) may require larger weight losses to convert to nonoverweight status, and more modest goals (eg, a 5%-10% reduction in BMI percentile) may be indicated to improve current and future health.[34,35] However, weight loss estimates for these children will likely increase with age. For example, an 8-year-old girl at the 97th BMI percentile would need to lose 1.8 kg to achieve nonoverweight status in 1 year; that target increases to 7.6 kg for the same girl just 4 years later, at age 12. Given the average weight gain trajectory for untreated youth, one could easily see how that child could eventually carry an excess 30 kg or more in adulthood; weight normalization at that point would clearly be a much more difficult undertaking. This underscores the need for early intervention and should encourage health care providers to engage patients in weight management to minimize weight gain and health complications later in life.

Our longitudinally derived weight change targets for shifting children to nonoverweight status compare relatively well with those derived using CDC normative data. For example, on the basis of observed height growth in our sample, a weight change of +3.9 to −2.9 kg in a hypothetical child presenting between the 90th and 95th age- and sex-adjusted BMI percentiles would result in nonoverweight status after 1 year. On the basis of actual weight change data in our sample, a child between the same adjusted BMI percentiles would need to lose 2.4 kg to achieve nonoverweight status after 1 year. Weight-change targets derived from the CDC data are remarkably similar, estimating that a weight change of +4.1 to −2.1 kg in a child presenting between those same adjusted BMI percentiles would result in nonoverweight status after 1 year. Thus, although CDC data are based on cross-sectional observations, they appear to provide good estimates of weight changes compared with those gleaned from observations over time. Health care providers should feel comfortable using CDC data to calculate weight-change targets for their patients, especially because these data are representative of the national population and are applicable to children at different height percentiles.

Generally, our data show that older children need to lose more weight (or conversely, to gain less weight) than younger children to achieve nonoverweight status. Given that younger children can anticipate more future growth than those who have initiated or completed puberty, this highlights the importance of early identification and treatment of PO. Interventions targeting preadolescents have produced successful outcomes,[36,37] and some data indicate that younger age predicts greater BMI *z* score reduction on treatment completion.[21] Younger children may be optimal targets for indicated prevention of adult obesity, although weight control treatment for overweight youth at any age is well advised.

Health care providers treating PO may espouse 1 of 2 contrasting perspectives: that children will naturally "outgrow" their obesity and do not require intervention, or that lengthy, intensive treatment is necessary to normalize children's weight status.[38] However, we have demonstrated that using family-based behavioral treatment, relatively small weight-for-height change can potentiate weight normalization in children, especially those closer to the 85th BMI percentile. Thus, a moderate approach may be sufficient for helping youth who are not severely overweight achieve nonoverweight status. For example, intervening as a child's BMI moves above the "normal" curve may necessitate minimal behavioral changes to shift that child back to nonoverweight status. How much intervention is required to shift a child's BMI trajectory to a healthier path likely differs by individual, and future research should clarify the intensity of intervention necessary for children in different ranges of the overweight spectrum. However, the changes observed in the current study were achieved using family-based behavioral treatment, and it is unclear whether less intensive approaches (eg, using select components of more intensive interventions) are effective in producing relative weight change. A stepped-care approach may be indicated whereby a less intensive intervention is replaced by a more intensive intervention in the absence of significant weight change.[39]

Although our data resulted from family-based PO treatment, the implications apply to any weight control intervention. Given differing nutritional needs within and across individuals throughout development,[40] caloric and physical activity goals may require tailoring to help children meet their weight loss goals: for example, calorie limits may need to be increased during puberty or when children are losing weight too rapidly. Even children in whom modest weight gain is indicated to reach nonoverweight status (eg, younger children or those presenting at lower BMI percentiles) will require an energy deficit to avoid maintenance of overweight status along with height growth. Moreover, once weight normalization is achieved, behavioral changes must be sustained to assist children in achieving weight change commensurate with height growth to prevent return to overweight status, and continued engagement in healthy weight-related behaviors will be needed to maintain a nonoverweight trajectory into adulthood. Maintenance treatments may be promising in this regard.[22]

A study limitation is that weight loss targets assume average stature and growth and hence will not apply to all children. In addition, height changes in our empirical sample were observed during and after PO treatment, which could limit the generalizability of our data to non–treatment-seeking youth. However, moderate weight change appears to have minimal effect on growth in overweight children,[17] which minimizes this concern. Finally, some of the sample sizes for deriving height change estimates and calculating observed weight changes were relatively small, thus results should be replicated. Strengths include the longitudinal design as well as the presentation of specific weight-change targets for children of varying ages, sexes, and anthropometric characteristics, which adds substantially to the existing literature and may assist with treatment planning.

Obesity has reached epidemic proportions, and it poses a burden to the individual and the public. Our findings highlight the need for rapid identification and intervention delivery to curtail further weight gain and mounting individual and societal costs. Although there are currently no established methods for preventing adult obesity, given that PO increases risk for adult obesity, it is reasonable to assume that reversing overweight status in childhood could decrease adult obesity risk. Indeed, 30% of youth receiving PO treatment are no longer obese in late adolescence or early adulthood, with shorter-term percentage overweight change best predicting long-term outcome.[41] Future research should investigate whether attainment of nonoverweight status in childhood improves other health outcomes in adulthood.[42] In summary, this study provides evidence that one aspect of indicated prevention, namely, normalizing weight status in childhood, is achievable through modest weight changes in growing children using intensive, family-based treatment. Continuing to develop and refine approaches for achieving this outcome is an important next step toward helping to stem the obesity epidemic in this country and worldwide.

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