From Calories to Weight Change in Children and Adults: The State of the Science

Healthy Eating Research
Building evidence to prevent childhood obesity

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Introduction

While recent data have shown signs of leveling among younger children, the rise in childhood obesity is one of the most urgent threats to the health of our nation. From the 1970s to the present, obesity rates more than quadrupled among children ages 6 to 11 and more than tripled among adolescents ages 12 to 19.[1,2] These staggering increases can in part be linked with the changing food environment, which has increased the availability of foods and beverages that are low in nutrients and high in unhealthy fats, added sugars, and calories. At the same time, the nation has experienced social and environmental changes that have reduced opportunities for children to be physically active.

Excess weight gain occurs when more calories are consumed than expended over a long period of time. With few children in the United States consuming diets that meet national guidelines for good health, such as the *Dietary Guidelines for Americans*, and even fewer getting the 60 minutes of recommended daily physical activity, it should be no surprise that currently more than one third of U.S. children and adolescents are affected by overweight or obesity. Further, many are suffering from associated conditions once thought to only impact adults, such as high blood pressure and joint problems, and some youth have developed type 2 diabetes.[3] As a result, clinical and public health interventions focusing on promoting physical activity, healthy eating, or both have gained traction at the local, state, and federal levels.

But how much weight change can be expected for a given change in food intake or physical activity? Accurate translation between changes in calories and changes in weight is important for setting goals and for evaluating interventions at both the individual and population levels. For years, reputable organizations around the world, as well as countless textbooks and websites, have used a simple rule of thumb for predicting weight change: 3,500 calories equals one pound of body weight change.[4-7] Using this rule, individuals may be told to cut 500-1,000 calories a day (the equivalent of a small order of French fries and a cheeseburger) from their diet, and expect to achieve one to two pounds of weight loss per week.[8] Similarly, the same rule of thumb has been erroneously used to predict the effect of policy changes on population obesity prevalence.[9] However, emerging research demonstrates that the math is not that straightforward, and the 3,500-calorie rule will create overly optimistic predictions of weight loss, oftentimes being in error by many fold.[10]

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The Evidence

When energy in (i.e., calories consumed) is consistently larger than energy out (i.e., calories burned), an individual gains weight. The reason that the 3,500-calorie rule fails to correctly predict weight loss or gain is because it does not account for the fact that the human body adapts the calories it burns to the changes in diet as weight is gained or lost.[8] For example, when an individual consumes more calories than in the past, there will be initial weight gain, but the body will react by ramping up calorie expenditure to sustain the now-heavier body weight, eventually reaching a new equilibrium where calories in equals calories out again.[11] Similarly, when an individual reduces calories in his/her diet, the body shifts into a "conservation" mode and metabolism slows to lessen the calorie imbalance and weight loss, eventually resulting in a weight plateau after some time. Simply, a larger body mass requires more fuel to sustain itself than a smaller one. This process has been studied extensively with overfeeding experiments and weight loss trials.[12] As a result, new mathematical models have been developed that are based on the energy balance principal and account for changes in the body's metabolism when diet and physical activities are altered. The models can be used to calculate the impact of calories on body weight in both adults and children.[13-15] For those ages 18 and older, the National Institutes of Health (NIH) Body Weight Planner (*http://BWplanner.niddk.nih.gov*) allows users to make personalized calorie and physical activity plans to reach a goal weight within a specific time period and to maintain it afterwards.

While the full models are required to make personalized predictions, several useful rules of thumb have been gleaned to estimate changes at the population level. For adults, the correct rule of thumb is that every pound of weight change requires a sustained, daily change of ten calories, with 50 percent of the weight change occurring in the first year and 95 percent of the rest occurring in three years. Therefore, an adult who wants to lose 15 pounds needs to permanently eliminate 150 calories (or a typical bag of chips) from his/her everyday diet and can expect to lose 7.5 pounds in the first year and an additional 7.5 pounds over the next three years, assuming that no other changes occur to their diet or physical activities.[14]

Predicting the caloric equivalent of excess weight in children is more complicated because a growing child is, in a sense, a moving target whose caloric needs change as the child grows and develops. While for adults a weight change occurs over a three-year period, the process happens more quickly in children. As a child ages, the timeframe slows to approach that of an adult. Simplified rule of thumb formulas resulting from these models can be applied to boys and girls, but only when examining calorie intake at a specific point in time. These formulas below were originally created for weight measured in kilograms (kgs), and have been adapted for using weight measured in pounds (lbs).[15]

Table. Excess weight of U.S. children from 7 to 18 years of age, and the corresponding additional calories consumed. Note that there is substantial variability around these estimates due to heterogeneity and sampling variability in NHANES.

Age	Boys, Weight Change from 1976-80 to 2003-06		Girls, Weight Change from 1976-80 to 2003-06	
	Excess Weight	Excess Intake	Excess Weight	Excess Intake
7 years	3.7 lbs	85 kcal/day	6.6 lbs	139 kcal/day
8 years	11.0 lbs	238 kcal/day	7.0 lbs	142 kcal/day
9 years	6.6 lbs	135 kcal/day	10.3 lbs	198 kcal/day
10 years	13.0 lbs	251 kcal/day	18.9 lbs	343 kcal/day
11 years	17.6 lbs	320 kcal/day	17.6 lbs	301 kcal/day
12 years	15.0 lbs	255 kcal/day	13.6 lbs	220 kcal/day
13 years	17.4 lbs	276 kcal/day	12.3 lbs	186 kcal/day
14 years	15.0 lbs	220 kcal/day	9.2 lbs	130 kcal/day
15 years	21.8 lbs	295 kcal/day	9.5 lbs	124 kcal/day
16 years	20.2 lbs	251 kcal/day	10.3 lbs	125 kcal/day
17 years	14.1 lbs	158 kcal/day	14.3 lbs	159 kcal/day
18 years	6.4 lbs	64 kcal/day	20.7 lbs	209 kcal/day
Average	**13.5 lbs**	**212 kcal/day**	**12.5 lbs**	**190 kcal/day**

Boys: Additional daily calories required per pound of excess weight can be calculated by multiplying the boy's age by a factor of 1.1 and subtracting the result from 31 [Excess calories required per pound of excess weight = 31-(1.1×Age)]. For example, a 10-year-old boy who has regularly consumed 110 extra calories per day for at least a year (about one order of children's French fries at a fast-food restaurant) would be 5.5 pounds heavier compared to his peer who had not eaten these added calories. This is because 5.5 lbs = 110 ÷ [31-(1.1×10 y)].

Girls: Additional daily calories required per pound of excess weight can be calculated by subtracting the girl's age from 28 [Excess calories required per pound of excess weight = 28-Age]. For example, a 10-year-old girl would be a little over 6 pounds heavier than her peer by consuming the same daily 110 calorie order of fries as the boy. This is because 6.1 lbs = 110 ÷ (28-10 y).

At the population level, these rules can be applied to understand the magnitude of interventions needed to close the "energy gap" that is contributing to childhood overweight and obesity. For example, an average 8-year-old U.S. boy measured in the National Health and Nutrition Examination Survey (NHANES) 2003-06 was 11 lbs heavier than the average 8-year-old boy in NHANES 1976-80 (see Table). This level of excess weight was a result of an average daily energy surplus of about 240 calories (11 lbs × [31-(1.1×8 years)] ~ 240 calories). For an average U.S. girl of the same age, the estimated difference in weight from 1976-80 to 2003-06 was 7 lbs, which corresponds to an excess of approximately 140 calories a day (7 lbs × (28-8 years) ~ 140 calories).

On average, reducing energy intake by about 200 kcal would have returned the mean bodyweight among children during the 2003-2006 years to levels characteristic of the late 1970s (i.e., before the onset of the childhood obesity epidemic). It is important to note, however, that for children falling into the obese category, a much larger change in daily calories was needed to arrive at the elevated weight, and similarly a much larger cut in calories would be needed to achieve a healthy weight.[16]

These models provide a more accurate framework than the old 3,500-calorie-per-pound rule of thumb to assess the intensity of behavioral changes needed for weight management. For example, consider a 10-year-old girl who is currently 20 lbs overweight according to growth charts, but five years ago was within the normal weight range for her age. Using the outdated 3,500-calorie rule, one would have concluded that she consumed approximately an extra 40 kcal/day over the previous five-year period. But in fact, using the correct rule, she has been eating roughly 400 kcal/day in excess of a peer who stayed within the normal range. Therefore, much larger changes are required to address the energy balance problem than was previously believed.

Conclusions

These models have serious implications for the prediction of reducing obesity at the population level and ways to prioritize different options or interventions to reduce caloric or energy intake.[17] Accurately predicting expected weight changes following adjustments in dietary intake is an important factor for evaluating the potential of interventions to impact obesity. Widespread use of the outdated 3,500-calorie rule has led to vast overestimation of predicted weight changes, which misleads clinicians, patients, and public health agencies in setting goals and tracking progress. The old rule should therefore be abandoned, as recommended by the American Society for Nutrition,[18] and replaced by the updated mathematical models discussed in this brief. These models of human metabolism in children and adults provide more accurate and realistic predictions of body weight change.

Policy and Practice Implications

Clinical practitioners and public health agencies that aim to design, implement, and evaluate interventions to address the energy imbalance and promote healthy weight should be aware that using the 3,500-calorie rule will lead to erroneous and inflated weight change predictions. The updated calculations discussed in this brief are essential in setting realistic expectations for interventions and establishing science-based guidelines to guide obesity prevention efforts. The current state of evidence suggests the obesity epidemic was driven by much larger changes in calorie intake than previously believed and will require aggressive strategies to reverse. There is likely no one silver bullet that can reverse the obesity epidemic, but rather multiple interventions in different settings will be required to achieve a sustained weight change at both the individual and population levels. These updated model calculations provide a platform for evidence-based dialogue on new program and policy approaches to address childhood obesity.

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References

1. National Center for Health Statistics. *Health, United States, 2012: With Special Feature on Emergency Care.* Hyattsville, MD; 2013.
2. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*. 2014;311(8):806-14.
3. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis. *BMC Public Health*. 2009;9:88.
4. Duyff RL. *American Dietetic Association Complete Food and Nutrition Guide*. 3rd Edition. Hoboken, NJ: John Wiley & Sons, Inc; 2006.
5. National Institutes of Health, National Heart, Lung and Blood Institute (NHLBI). *Aim for a Healthy Weight*. Bethesda, MD: NIH NHLBI, 2005:36.
6. National Heart, Lung, and Blood Institute (NHLBI) Obesity Education Initiative Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults. *The Practical Guide: Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*. Bethesda, MD: NIH NHLBI; 2000.
7. National Health Service (NHS). *Your Weight Your Health: How to take control of your weight*. London: NHS Department of Health; 2006.
8. Guth E. JAMA patient page. Healthy weight loss. *JAMA*. 2014;312(9):974.
9. Lin BH, Smith TA, Lee JY, Hall KD. Measuring weight outcomes for obesity intervention strategies: The case of a sugar-sweetened beverage tax. *Econ Hum Biol*. 2011;9(4):329-41.
10. Brown AW, Hall KD, Thomas D, Dhurandhar NV, Heymsfield SB, Allison DB. Order of Magnitude Misestimation of Weight Effects of Children's Meal Policy Proposals. *Child Obes.* 2014;10(6):542-545.
11. Katan MB and Ludwig DS. Extra calories cause weight gain--but how much? *JAMA*. 2010;303(1):65-6.
12. Westerterp KR. Metabolic adaptations to over--and underfeeding--still a matter of debate? *Eur J Clin Nutr*. 2013;67(5):443-5.
13. Hall KD. Modeling metabolic adaptations and energy regulation in humans. *Annu Rev Nutr*. 2012;32:35-54.
14. Hall K., Sacks G, Chandramohan D et al., Quantification of the effect of energy imbalance on bodyweight. *Lancet*. 2011;378(9793):826-37.
15. Hall KD, Butte NF, Swinburn BA, Chow CC. Dynamics of childhood growth and obesity: Development and validation of a quantitative mathematical model. *Lancet Diabetes Endocrinol*. 2013;1(2):97-105.
16. Wang YC, Gortmaker SL, Sobol AM, Kuntz KM. Estimating the energy gap among US children: A counterfactual approach. *Pediatrics*. 2006;118(6):e1721-33.
17. Wang YC, Hsiao A, Orleans CT, Gortmaker SL. The Caloric Calculator: Average Caloric Impact of Childhood Obesity Interventions. *Am J Prev Med.* 2013;45(2):e3-e13.
18. Hall KD, Heymsfield SB, Kemnitz JW, Klein S, Schoeller DA, Speakman JR. Energy balance and its components: Implications for body weight regulation. *Am J Clin Nutr*. 2012;95(4):989-94.

About Healthy Eating Research

Healthy Eating Research (HER) is a national program of the Robert Wood Johnson Foundation. Technical assistance and direction are provided by Duke University and the University of Minnesota School of Public Health under the direction of Mary Story, PhD, RD, program director, and Laura Klein, MPH, deputy director. HER supports research to identify, analyze, and evaluate environmental and policy strategies that can promote healthy eating among children and prevent childhood obesity. Special emphasis is given to research projects that benefit children and adolescents and their families, especially in lower-income and racial and ethnic populations at highest risk for obesity. For more information, visit *www.healthyeatingresearch.org* or follow HER on Twitter at *@HEResearch*.

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